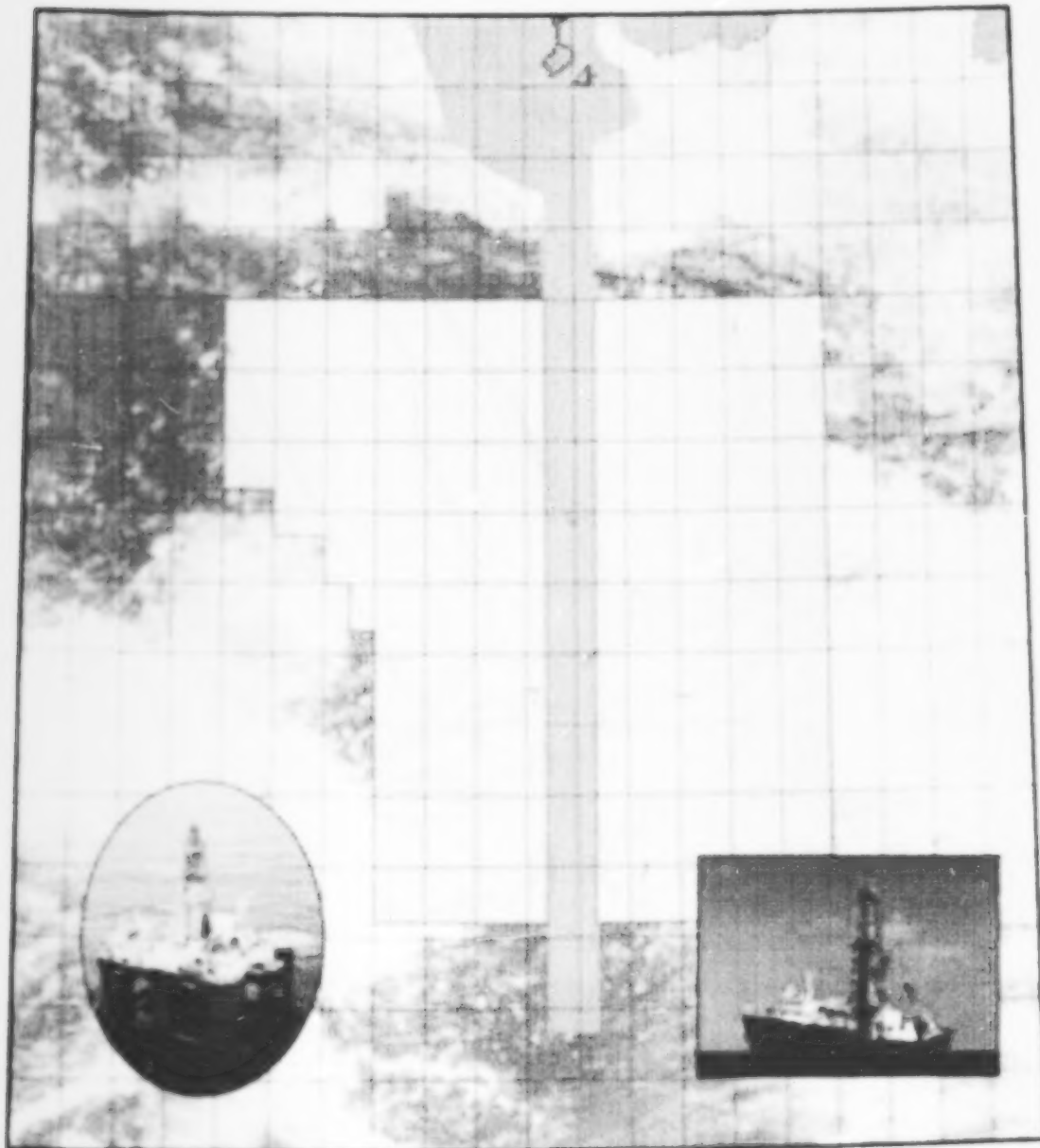


STRATEGIC ENVIRONMENTAL ASSESSMENT LAURENTIAN SUBBASIN



Final Report



JW PROJECT NO. NFS08932

**STRATEGIC ENVIRONMENTAL ASSESSMENT
LAURENTIAN SUBBASIN**

NOVEMBER 2003

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**STRATEGIC ENVIRONMENTAL ASSESSMENT
LAURENTIAN SUBBASIN**

SUBMITTED TO:

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LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
ADW	Approval o Drill a Well
API	American Petroleum Institute
BOP	Blowout Preventer
BPD	Barrels per Day
CAPP	Canadian Association of Petroleum Producers
CEAA	<i>Canada Environmental Assessment Act</i>
cm	Centimetre
C-NOPB	Canada-Newfoundland Offshore Petroleum Board
C-NSOPB	Canada-Nova Scotia Offshore Petroleum Board
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPR	Continuous Plankton Recorder
CV	Coefficient of Variation
dB	Decibel
DFO	Department of Fisheries an Oceans
DPA	Drilling Program Authorization
EEM	Environmental Effects Monitoring
EEZ	Exclusive Economic Zone
EMOBM	Enhanced Mineral Oil-based Mud
EPA	Environmental Protection Agency
EPP	Environmental Protection Plan
ESRF	Environmental Studies Research Funds
ETL	Effects Threshold Level
FEAC	Fisheries and Environmental Advisory Committee
FLO	Fisheries Liaison Officer
Hz	Hertz
ICATT	International Commission for the Conservation of Atlantic Tuna
ICES	International Council for Exploration of the Seas
IIP	International Ice Patrol
JNCC	Joint Nature Conservation Committee
kHz	Kilohertz
km	Kilometre
km/h	Kilometre per Hour
kts	Knots
L	Litre
m	Metre
mg/kg	Milligram per Kilogram

MMS	Minerals Management Service
m/s	Metres per Second
ms	Millisecond
NAFO	North Atlantic Fisheries Organization
NEB	National Energy Board
NL	Noise Level
NMFS	National Marine Fisheries Service
OCSG	Offshore Chemical Screening Guidelines
OWTG	Offshore Waste Treatment Guidelines
PAH	Polycyclic Aromatic Hydrocarbon
PBR	Potential Biological Removal
PERD	Panel on Energy Research and Development
ppb	Parts per Billion
ppt	Parts per Thousand
PRAC	Petroleum Research Atlantic Canada
PSI	Pounds per Square Inch
ROV	Remotely Operated Vehicle
SBM	Synthetic-based mud
SEA	Strategic Environmental Assessment
SL	Source Level
SPL	Sound Pressure Level
TL	Transmission Loss
TOC	Total Organic Carbon
TTS	Temporary Threshold Shift
UKOOA	United Kingdom Offshore Operators Association
VEC	Valued Environmental Component
VSP	Vertical Seismic Profile
WBM	Water-based Mud

1.0 INTRODUCTION

This report provides a Strategic Environmental Assessment (SEA) of potential oil and gas exploration in the Laurentian Subbasin.

1.1 Background

The Laurentian Subbasin is located to the south of the Island of Newfoundland, and surrounds the "French Corridor" south of the islands of St. Pierre and Miquelon (Figure 1.1). Although relatively unexplored at present, the subbasin is thought to have petroleum resource potential. Exploration rights in this region are held under exploratory permits issued by the Government of Canada in 1969 and 1971, which cover an area of approximately 3.3 million hectares. The recent establishment of boundaries delineating the Newfoundland and Labrador and Nova Scotia Offshore Areas within this region has prompted increased interest in exploration drilling in the Laurentian Subbasin.

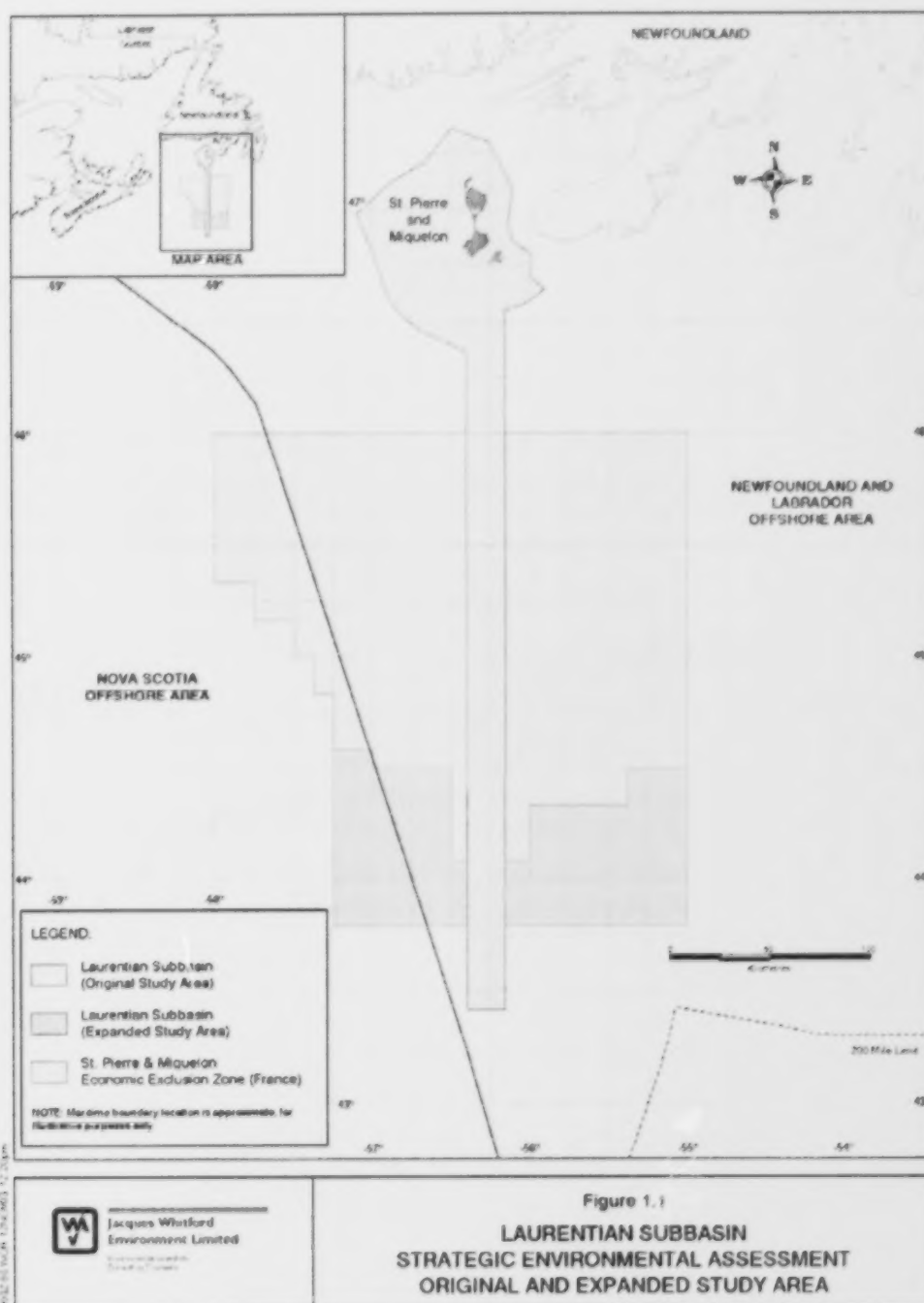
The Canada-Newfoundland Offshore Petroleum Board (C-NOPB) and the Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB) intend to negotiate the conversion of the existing federal exploratory permits for their respective offshore areas in the Laurentian Subbasin into exploration licences. As a consequence, exploration drilling (and, if successful, delineation drilling) may be proposed. It is also anticipated that seismic and other geoscientific surveys will be undertaken in the area. The Boards require a SEA of the Laurentian Subbasin region as part of the permit conversion process, and in anticipation of interest in the area.

1.2 Strategic Environmental Assessment: An Overview

Environmental assessment is a systematic process for analyzing and evaluating the potential environmental effects of proposed activities, and is an important means of incorporating environmental considerations into decision-making. Although environmental assessment has traditionally been applied primarily to individual projects, recent years have seen increased interest in its application to earlier stages of the planning process, namely, policies, plans and programs. SEA has been defined as:

[T]he formalized, systematic and comprehensive process of evaluating the environmental impacts of a policy, plan or programme and its alternatives...and using the findings in...decision-making (Therivel et al. 1992: 19-20).

Figure 1.1 Laurentian Subbasin Strategic Environmental Assessment Study Area



SEA represents a broader, more proactive approach to assessing and managing environmental effects. SEAs typically focus on "regional-scale" environmental concerns, and allow any such issues to be considered early, before project-specific activities are defined. Because SEAs are undertaken early in the planning process, there is often little or no information available regarding the nature, timing and location of specific projects and activities. Therefore, these assessments usually focus on general environmental issues and describe potential effects in relatively broad terms. SEA is not meant as a replacement for project-specific environmental assessment processes. Rather, the objective is to provide the type and level of information necessary to aid decision-making at the early stages of the planning process.

1.3 Assessment Purpose and Context

The objective of this study is to complete a SEA of potential offshore oil and gas exploration within the Laurentian Subbasin study area (Figure 1.1). The assessment focuses on the "exploration phase" of offshore petroleum activity in the Laurentian Subbasin, including potential seismic surveys and drilling programs.

Originally, the study area was delineated by the boundaries of the federal permits. However, in anticipation of interest in the area, the Boards decided to increase the study area to the south of the original study areas.

An SEA for the 'original' study area was released for public comments in April 2003. In September 2003, an amendment to the SEA, to reflect the change in study area, was released for comment. This SEA presents an overview for the revised study area, incorporating, where appropriate, comments received during both reviews.

The SEA provides an overview of the existing environment of the Laurentian Subbasin, discusses in broader terms the potential environmental effects which may be associated with offshore oil and gas exploration in the study area, identifies knowledge and data gaps, highlights any key issues of concern, and makes recommendations for mitigation and planning. Information from the SEA will assist the C-NOPB and C-NSOPB in determining whether exploration rights should be offered in whole or in part for an area, and may also identify general restrictive or mitigative measures that may be considered for application to seismic and/or drilling activities.

Following the issuance of exploration licences, and seismic or other geoscientific surveys in the area, the drilling of wells (exploration or delineation) would be able to proceed in the Laurentian Subbasin. These activities will require review and approval by the C-NOPB and C-NSOPB, and will be subject to individual environmental assessments. Again, the SEA is not intended as a substitute for project-specific environmental assessments. However, it will provide individual operators with a general overview of the region's existing environmental setting, and help define key environmental issues and interactions

which may require consideration in the early planning phases of individual seismic surveys and drilling programs, as well as in their subsequent environmental assessments.

The SEA provides a description of the existing environmental setting in the study area based on existing, available information, and an overview of potential environmental issues at an early stage of the planning process. Changes in technology and/or advances in the understanding of the natural and socio-economic environments of the region may eventually require that the SEA be updated to reflect current information. A review of the SEA will be undertaken in five years to determine if such updates are required.

1.4 Document Organization

This report is organized as follows.

Chapter 1 provides an introduction to SEA, and includes background information on the Laurentian Subbasin and SEA in general, as well as the purpose and context of the assessment, and the organization of the document.

Chapter 2 provides an overview of the Laurentian Subbasin, including the planning and regulatory processes which apply to offshore exploration in the region, as well as past and potential seismic surveys and drilling programs within the study area. This is followed by a general, generic description of offshore petroleum exploration (including seismic surveys and well drilling).

Chapter 3 provides a description of the environmental setting of the Laurentian Subbasin, including its physical, biological, and socio-economic environments, based on existing, available information.

Chapter 4 describes the scope of the assessment, defining the specific components and activities under consideration, and the spatial and temporal boundaries of the SEA. It also describes the issue scoping exercise undertaken as part of the assessment, and identifies the specific Valued Environmental Components (VECs) upon which the SEA is focussed and the rationale for their selection. This chapter also provides an overview of the approach and methodology used to conduct the SEA.

Chapter 5 provides the environmental effects analysis for each of the VECs under consideration. Each VEC is discussed in a separate section, which includes a discussion of:

- potential environmental interactions and existing knowledge regarding them, as well as standard mitigation measures that may be applied to seismic surveys and drilling programs to avoid or reduce potential environmental effects;
- key environmental planning and management considerations and any additional activity, site or time-specific mitigation measures which may be required;

- the nature and adequacy of available information for the study area and relevant data requirements;
and
- potential cumulative environmental effects.

Chapter 6 presents a summary of the key findings and conclusions of the assessment.

References, including personal communications and the literature cited, are provided in Chapter 7.

Supporting information is provided in the Appendices.

2.0 OIL AND GAS EXPLORATION IN THE LAURENTIAN SUBBASIN

The following sections provide an overview of the regulatory and planning processes which apply to offshore seismic surveys and drilling programs in the Laurentian Subbasin. This is followed by a general description of the components and activities which are typically associated with these activities.

2.1 Regulatory and Planning Processes

The C-NOPB is responsible, on behalf of the Government of Canada and the Government of Newfoundland and Labrador, for petroleum resource management in the Newfoundland and Labrador Offshore Area. The *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* are administered by the C-NOPB and govern all petroleum operations in the offshore area. The Board's responsibilities under the Acts include: the issuance and administration of petroleum exploration and development rights; administration of statutory requirements regulating offshore exploration, development and production; and approval of Canada-Newfoundland and Labrador Benefits Plans and Development Plans (C-NOPB n.d.).

The C-NSOPB is a joint independent agency of the Canadian and Nova Scotia governments, and is responsible for the regulation of petroleum affairs and safe practices offshore Nova Scotia. The Board operates under the authority of the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act* and the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act*. The Board's principal responsibilities include: ensuring the safe conduct of offshore operations; protection of the environment during offshore petroleum activities; management of offshore oil and gas resources; review of industrial benefits and employment opportunities; issuance of licences for offshore exploration and development; and resource evaluation, data collection and distribution (C-NSOPB n.d.).

2.1.1 Rights Management Process

Administration of the land tenure and rights issuance system is one of the central functions of the Boards. Three documents of "title" apply to the offshore areas: the exploration licence, significant discovery licence, and production licence.

2.1.1.1 Exploration Licence

An exploration licence is required to undertake exploratory drilling in the Newfoundland and Labrador and Nova Scotia Offshore Areas (an exploration licence is not required to conduct seismic surveys).

Issuance of an exploration licence is a "fundamental decision" under the *Accord Acts* and requires Ministerial approval. An exploration licence confers:

- the right to explore for, and the exclusive right to drill and test for, petroleum;
- the exclusive right to develop those portions of the offshore area in order to produce petroleum; and
- the exclusive right, subject to compliance with the other provisions of the Acts, to obtain a production licence.

Exploration licences are typically issued for a maximum nine-year term, which consists of two consecutive periods, usually five years (Period I) followed by four years (Period II). The interest owner is required to drill or spud and diligently pursue one exploratory well on or before the expiry date of Period I. Failure to drill or spud a well will result in reversion to Crown reserve of the licence. If the license requirement is fulfilled, the interest owner is entitled to obtain tenure to Period II.

2.1.1.2 Significant Discovery Licence

At the expiration of an exploration licence, the portions of the offshore area not subject to a significant discovery licence or production licence revert to the Crown. If a drilling program results in a significant discovery and a declaration of significant discovery has been made by the Board, an interest owner is entitled to a significant discovery licence. A significant discovery licence confers the same rights as those of an exploration licence, and is of no definite term. The significant discovery licence is subject to annual rents on a per hectare basis.

2.1.1.3 Production Licence

Where a commercial discovery is declared by the Board, the interest owner may apply for a production licence. A declaration of commercial discovery is a pre-condition to the issuance of the production licence. A production licence confers:

- the right to explore for, and the exclusive right to drill and test for, petroleum;
- the exclusive right to develop those portions of the offshore area in order to produce petroleum;
- the exclusive right to produce petroleum from those portions of the offshore area; and
- title to the petroleum so produced.

Other agencies may also issue permits and approvals related to offshore activities in the Newfoundland and Labrador and Nova Scotia Offshore Areas.

2.1.2 Laurentian Subbasin – Permit Conversion Process

Exploration rights in the Laurentian Subbasin are held under exploratory permits issued by the Government of Canada in 1969 and 1971, which cover an area of approximately 3.3 million hectares. Federal regulations establishing the marine boundary between the Newfoundland and Labrador and Nova Scotia Offshore Areas in the region (Figure 1.1) were promulgated in June 2003. The C-NOPB and the C-NSOPB intend to negotiate the conversion of these existing federal exploratory permits for their respective offshore areas in the Laurentian Subbasin into exploration licences.

The Boards have commenced negotiations with the representatives for the three major blocks within the Laurentian Subbasin (ExxonMobil, ConocoPhillips and Imperial). The legislation provides for a six-month period to complete this process. It is anticipated that the term of the resulting licences will be nine years, with periods within that term to encourage early exploration.

2.1.3 Authorizations Required for Exploration

The Boards' regulatory roles include the issuing of specific approvals and authorizations pertaining to offshore seismic surveys and drilling programs. The following sections provide a brief overview of these authorizations.

2.1.3.1 Newfoundland and Labrador

Operating Licence

An Operating Licence is a prerequisite for any exploratory activity in the Newfoundland and Labrador Offshore Area which involves field work. Any individual or corporation may apply to the C-NOPB for an operating licence by completing and forwarding the appropriate application to the Board. An operating licence is valid from its commencement date to March 31 next following its date of issuance (C-NOPB n.d.).

Authorization for Geophysical Surveys

Any program involving field work (including seismic and other geoscientific surveys) must be authorized by the C-NOPB prior to its commencement. Applications for such programs must be submitted to the Board for approval at least 60 days in advance of the proposed commencement date, and include the following information:

- Program Description;
- Safety of Operations;
- Canada-Newfoundland and Labrador Benefits;

- Environmental Protection; and
- Financial Responsibility.

As part of the application process, the C-NOPB requires that applications for programs involving field work include an environmental assessment of the proposed operation, consistent with the requirements of the *Canadian Environmental Assessment Act* (CEAA) and suitable for public release (C-NOPB 2001).

While an exploration licence is required to undertake drilling activity, such a licence is not required to conduct seismic surveys. Therefore, seismic survey areas often extend beyond exploration licence boundaries.

Drilling Program Authorization and Approval to Drill a Well

Operators are required to obtain a Drilling Program Authorization (DPA) and Approval to Drill a Well (ADW) prior to conducting drilling operations.

The DPA authorizes an operator to conduct a drilling program, consisting of one or more wells within a specified area and time using one or more drilling installations, and includes all operations and activities ancillary to the program. The drilling program commences upon spudding the first well in the program and is authorized for three years from the date of issuance of the authorization. Information required as part of the DPA process include:

- Canada-Newfoundland and Labrador Benefits Plan;
- Evidence of Financial Responsibility;
- Declaration of Fitness;
- Certificate of Fitness;
- Standby Vessels;
- Safety Assessment; and
- Occupational Health and Safety Plan.

The C-NOPB also requires that proponents prepare and submit an environmental assessment as part of an application for a DPA for offshore oil and gas exploration projects (C-NOPB 2000).

An ADW permits the operator to drill a particular well using the drilling and evaluation procedures described in the application and accompanying well prognosis. The submission of an application for an ADW is preceded or accompanied by documentation showing that the operator has investigated the nature of the seafloor and underlying sediments to identify any potential surface or subsurface hazards (such as shallow gas). A copy of the well prognosis and tentative survey plan of the well location must

also be provided with the application. An ADW is conditional upon the operator commencing drilling within 120 days of the day the approval was granted.

Once approval has been obtained and exploration commences, there are specific recording and reporting requirements which operators must also adhere to (C-NOPB 2000).

2.1.3.2 Nova Scotia

In Nova Scotia, the issuance of an Exploration Licence likewise does not give an operator the right to conduct offshore oil and gas activities. Prior to conducting any oil and gas activities, Exploration Licence holders must get separate Board approval for each activity they plan. The approvals process for offshore seismic surveys and drilling programs in Nova Scotia closely mirrors that of Newfoundland and Labrador, and includes requirements for an Operating Licence, Authorization for Geophysical Surveys, DPAs and ADWs. When applying for Board authorizations, companies must file comprehensive documentation (including, among other things, an environmental assessment and an environmental protection plan). This process provides ongoing opportunities for fishing interests, other ocean resource users, the academic community, government scientists, and the general public to comment on proposed exploration licences and activities (C-NSOPB n.d.).

2.1.4 Environmental Assessment

As noted, both the C-NOPB and C-NSOPB require environmental assessments as part of the approvals process for offshore seismic and drilling activities. Other agencies may also issue permits and approvals related to offshore activities, and require environmental assessments prior to issuing these authorizations.

A number of environmental assessments have been conducted to date in relation to specific seismic surveys and drilling programs in the Newfoundland and Labrador and Nova Scotia Offshore Areas. Environmental assessments for these activities typically include the following:

- a detailed description of the proposal;
- an overview of the existing physical, biological and socio-economic environments;
- an assessment of the potential environmental effects of planned activities and potential accidental events;
- the identification of mitigation measures to avoid or reduce predicted environmental effects;
- an evaluation of the significance of the remaining residual environmental effects;
- an assessment and evaluation of any likely cumulative environmental effects; and
- information on any proposed follow-up programs.

Detailed studies conducted in support of environmental assessments for proposed drilling programs may include:

- an analysis of meteorological and oceanographic conditions;
- dispersion modelling for drill muds and cuttings discharges;
- blowout and spill probability assessments; and
- modelling studies of the fate and behaviour of hypothetical oil spills.

Environmental assessment of offshore seismic surveys and drilling programs in the Newfoundland and Labrador and Nova Scotia Offshore Areas may be subject to the requirements of the CEAA following amendments to that Act scheduled for 2003.

Under CEAA, federal decision-makers are required to consider a project's environmental effects whether they occur within or outside Canada. In addition, in May 1998, Canada ratified the United Nations Economic Commission for Europe *Convention on Environmental Impact Assessment in a Transboundary Context*. The Convention (concluded at Espoo, Finland) is the first major international agreement of its kind, and outlines specific obligations to minimize significant adverse transboundary environmental effects of certain projects, defines environmental assessment requirements, and outlines general obligations of countries to notify and consult each other on all major projects under consideration that are likely to have environmental effects across boundaries (Agency n.d.).

2.2 Generic Description of Offshore Exploration

The following sections provide a general discussion of seismic surveys and drilling programs as these are typically conducted in Atlantic Canada. More detailed descriptions of these activities can be found in other sources (e.g., Davis et al. 1998; LGL Limited et al. 2000).

2.2.1 Offshore Seismic Surveys

Seismic surveys are used to identify geological formations that may contain petroleum resources (hydrocarbon traps). A summary description of seismic survey vessels and techniques is provided in the following sections.

2.2.1.1 Equipment and Methods

An offshore survey vessel is typically 80 to 95 m long, with a crew of approximately 40 personnel (Davis et al. 1998). In an offshore seismic survey, a high-energy sound source (in the form of one or more airguns), is towed at 4 to 10 m below the water surface behind a survey vessel. The vessel travels along a track line in a prescribed grid at a speed of approximately 3.5 to 5.5 knots (6.5 to 10 km/h). The survey track is carefully chosen to cross any known or suspected hydrocarbon prospects in the area.

The sound source is typically fired approximately every 25 m and, insofar as practical, directs bursts of sound downward toward the sea floor (a "shot"). Reflected sound energy from below the sea bottom are recorded by one or more sensitive hydrophone arrays (streamers) deployed and towed behind the survey vessel (Figure 2.1), which are typically 3 to 5 km long. Computer-based data processing systems convert the reflected sound (acoustic signals) into seismic data that can be used to map possible hydrocarbon accumulation.

Two-dimensional (2D) seismic surveys cover relatively large geographical areas and, hence, are of short-term duration at any given location. Survey lines tend to be over 1 km apart, and are often laid out in a number of different directions. The 2D survey is typically used for exploring a large area in order to identify areas which require further study (Davis et al. 1998), and use a single source array and a single streamer.

Three-dimensional (3D) seismic surveys enable a greater resolution of potential and existing oil and gas fields. These seismic surveys provide a detailed picture of the area under investigation, allowing for a more detailed analysis of the quantity and distribution of hydrocarbons (Davis et al. 1998). These can result in a reduced number of wells required to define a field and allow for optimal oil and gas recovery. Such surveys may concentrate activity over a relatively small geographical area for extended periods (often weeks at a time), with survey lines usually spaced several hundred metres apart. 3D surveys typically use two source arrays that alternate shooting, and multiple streamers.

Again, while an exploration licence is required to undertake drilling activity, such a licence is not required to conduct seismic surveys. Seismic survey areas therefore often extend beyond exploration licence boundaries.

Figure 2.1 Typical Seismic Survey

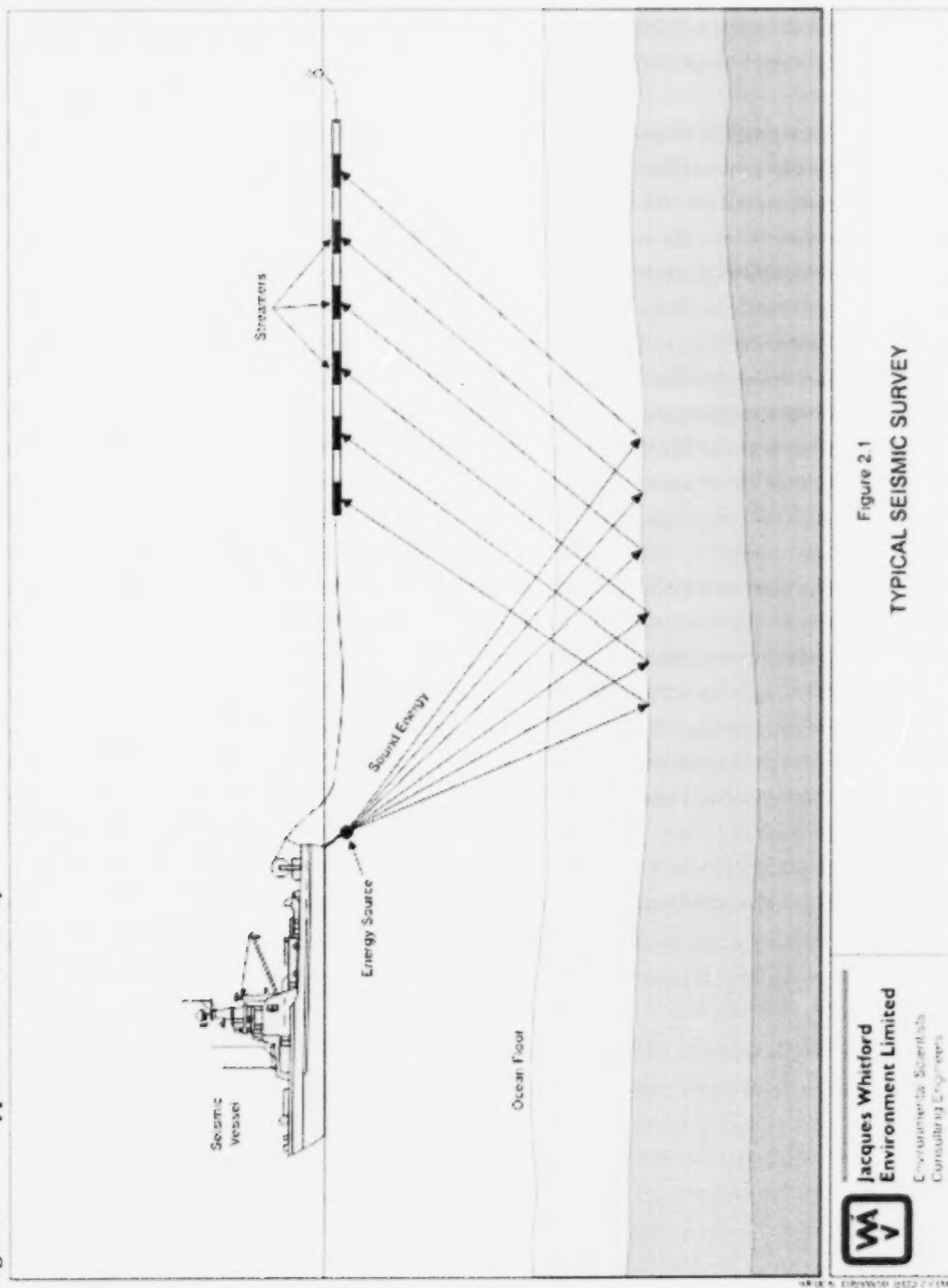


**Figure 2.1
TYPICAL SEISMIC SURVEY**

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2.2.1.2 Seismic Signals and Sound Propagation

In operation, airguns are usually fired at approximately 10-second intervals, with seismic shots being of short duration, at most a few tens of milliseconds (ms) (yielding a duty cycle of approximately 0.3 percent). Although peak energy levels within a shot may be high, the short signal duration reduces the total energy transmitted into the water column. Most of the sound energy produced by an airgun array is in the range of 10 to 300 hertz (Hz), with highest levels at frequencies of less than 100 Hz (Turnpenny and Nedwell 1994). Seismic air-guns are designed to produce low frequency noise, but research has shown that high frequency sound may also be produced, up to several kilohertz (kHz) (Goold 1996a; JNCC 1998). Other factors (e.g., rise times, etc.) also influence the characteristics of a seismic signal, and thus its potential environmental effects.

Airguns are usually used in arrays of 30 to 40 units rather than singly. This is done to increase the available acoustic output for greater penetration into the sea floor, to obtain greater source efficiency, and to shape the acoustic signature so that the resolution needed for a specific type of survey is obtained. The layout of the array and the sequence of firing are carefully designed to optimize the data. The total airgun volume in the array, and their operating pressure, determine the amplitude of the acoustic signal, measured as the output Sound Pressure Level (SPL). Marine airgun arrays normally have a combined chamber volume of between 2,000 and 4,000 cubic inches and operate at approximately 2,000 pounds per square inch (psi). The peak SPL generated by such an array would be between 240 and 260 dB re 1 μ Pa @ 1 m.

The design of an airgun array is intended to focus the acoustic emissions in the downward direction towards the substratum, a characteristic known as "directivity". This is done to minimize the amount of energy which is wasted by travelling in the wrong direction. It also serves to reduce the area of influence of the array. The sound from a seismic array diminishes (attenuates) with increasing distance from the source. Attenuation is fairly rapid close to the source, but is more gradual at longer distances because levels diminish as a function of the logarithm of the distance from the source. As this distance increases, the amplitude of the sound diminishes and the frequency spectrum broadens (Canning and Pitt 2002).

Most of the loss in pressure is the result of spreading in the water. In general, the diminishing of pressure with increasing distance from the source is spherical to a distance that is approximately equal to water depth. At greater distances, sound propagates through a channel bounded by the bottom and the water surface, and spreading is often assumed to be approximately cylindrical (Davis et al. 1998; Thomson et al. 2000).

Although this simple spreading model provides some general insight into the attenuation of sound from seismic surveys through the water column, a range of other activity and site-specific factors may also influence sound propagation in the marine environment. For example, sound levels and frequencies can vary, and oceanographic characteristics (e.g., physiography and water depth, temperature, salinity) can

also influence the attenuation of sound as it propagates through the water (Davis et al. 1998). Sound propagation in shallow, shelf areas, for example, is more strongly attenuated, especially at low frequencies, while sound is likely to propagate further in deeper waters, especially where acoustic channels exist. The attenuation characteristics of noise in the Laurentian Subbasin is likely complex, given the varied physiography of the region (Section 3.1.1). Transmission loss modelling for several tracks near Sable Island and in the Laurentian Channel are presented in Davis et al. (1998).

Detailed information on the characteristics and propagation of seismic signals can be found in other sources (e.g., Turnpenny and Nedwell 1994; Richardson et al. 1995; Davis et al. 1998).

Key factors which influence the potential environmental effects of sound from a seismic survey therefore include:

- the Source Level (SL) of the source, that is, the level of sound that it generates;
- the Transmission Loss (TL), that is, the attenuation of sound as it propagates through the water;
- the Effect Threshold Level (ETL) or level of sound at which a given effect occurs;
- the Noise Level (NL) or level of background noise, since under some circumstances this may have an effect in masking the effects of the sound source.

2.2.1.3 Vessel Traffic and Other Emissions

The vessel traffic associated with seismic surveys may also have implications for the natural and human environments in the survey area. Other operational emissions associated with seismic surveys include vessel discharges (e.g., deck drainage), atmospheric emissions (e.g., vessel exhaust) and the general presence of vessels and lights associated with offshore seismic survey activity.

2.2.1.4 Potential Accidental Events

Because seismic surveys do not result in the recovery of petroleum, the potential for, and the severity of, accidental events associated with such surveys are considerably lower than for drilling activities. As is the case for marine vessel activity of any sort, there is always the possibility of accidental events occurring at sea, ranging from small spills of fuel and other materials to possible collisions with marine life, fishing gear and/or other vessels. Any such events may have implications for human health and safety and the natural environment.

2.2.2 Well Drilling

Offshore exploration and delineation wells are drilled to confirm the presence, or define the extent, of petroleum resources in specific locations. Exploration wells are drilled to determine whether traps identified from previous seismic surveys contain petroleum resources. Depending on the results of these wells, an operator may then drill delineation wells into different parts of the hydrocarbon accumulation to confirm its size and the characteristics of the hydrocarbons found (CAPP 2001a).

The following sections provide a brief description of typical well drilling equipment and procedures which may be used to conduct offshore drilling in the Laurentian Subbasin.

2.2.2.1 Drilling Units

A number of types of offshore drilling units can be used to drill a well once a drill site or target is determined. Three different types of rigs are used for drilling offshore wells in Atlantic Canada (Figure 2.2):

1. Jack-Up Drilling Units;
2. Semi-Submersible Drilling Units; and
3. Drill Ships.

The type of rig chosen is based primarily on the characteristics of the physical environment at the proposed drill site, particularly water depth, expected drilling depth and required mobility under expected weather and ice conditions (CAPP 2001b). Generally, deep-water wells are defined as those drilled in water depths greater than 400 m. Shallow-water wells are in water depths of less than 400 m.

The Laurentian Subbasin has water depths ranging from relatively shallow (less than 100 m deep) in areas such as the St. Pierre Bank to deeper waters (greater than 400 to 500 m deep) in areas of the Laurentian Channel. Water depths at the edge of the Laurentian Channel near the shelf break drop off to depths greater than 2,000 m.

Figure 2.2 Typical Offshore Drilling Units



Jack-Up Drilling Unit



Semisubmersible Drilling Unit



Drill Ship

A brief description of the three types of drilling units is included below (CAPP 2001b).

Jack-Up Drilling Units are used in water depths of less than 100 m. These units are towed to the drill site, during which time the rig's retractable legs are retracted above the hull structure and the rig floats atop a barge. Once on site, the legs are lowered until they come into contact with the sea floor, and the drilling barge or unit platform is elevated up the legs until it is at the desired height above the water surface.

A *Semisubmersible Drilling Unit* is typically used in deeper waters or in areas where increased mobility is required, such as in ice-prone areas offshore Newfoundland. A series of vertical columns support the main deck of the unit, which in turn sit atop steel pontoons that float below the water surface during drilling. The pontoons are filled with water so that the unit floats with the main deck above water and the remainder below the water surface. Because much of the mass of the rig is below water, these units are relatively stable in rough seas. On site, the unit is moored to the bottom with a series of 8 to 12 anchors (which may extend up to 1 km from the rig). In deeper waters (1,000 to 2,000 m), semisubmersible drilling units often have a dynamic positioning system, which uses computer-controlled thrusters to position the vessel and keep it steady.

Drill Ships are the most mobile type of drilling unit, and are generally used in areas of relatively deep water. Drill ships have a series of thrusters or powered propellers fore and aft and on both sides of the vessel, with a computerized system that automatically activates the system to maintain the vessel's position. Drill ships can be anchored to the bottom in water depths of approximately 200 to 1,000 m, with dynamic positioning systems allowing some drill ships to operate in waters up to 3,000 m deep. A drill ship has a tall derrick in the centre of the vessel where a moon pool provides access from the deck surface through the centre of the ship to the water column. Drill ships generally cannot operate in as rough seas as semisubmersible units.

Each of these types of drill rigs are self-contained, and include a derrick and drilling equipment, a moon pool or some other form of access to the water surface, a helicopter pad, fire and rescue equipment and crew quarters. Drilling units also typically have one to three support vessels in attendance. Generally, drilling operations and discharges are similar for each type of drill rig (LGL Limited et al. 2000).

2.2.2.2 Drilling Activities

The following provides a general overview of the type of drilling activities that may occur in the Laurentian Subbasin. This discussion is based on existing descriptions of offshore drilling (LGL Limited et al. 2000; CAPP 2001a), and is intended to provide context for the SEA. Specific dimensions and depths are provided for illustration purposes only, based on recent drilling programs conducted in Atlantic Canada.

Offshore wells have four main components (CAPP 2001a):

- i. *Drill string*: the sections of drill pipe which connect the drilling rig and the drill bit located at the bottom of the well;
- ii. *Drill bit*: the device used to cut through the seabed to access the geological formation of interest;
- iii. *Rotation equipment*: which is used to turn the drill string, and thus, the drill bit; and
- iv. *Drilling fluid*: (or mud), which lubricates and cools the drill bit, counterbalances formation pressure, helps condition the wellbore and carries the rock cuttings away from the bit during drilling.

Offshore wells are typically drilled in a number of stages. Initially, a large diameter conductor hole (approximately 90 cm wide) is drilled several hundred metres into the seafloor. Water-based mud (WBM) is used to drill this portion of the well. Since there is no way to return the drilling muds and cuttings to the drilling unit before the riser is installed, the drilling muds and cuttings are released onto the seabed. The drill string is then removed, and a steel pipe ("casing") is run and cemented into place to prevent the wall of the hole from caving in and to prevent seepage of muds and other fluids. The surface casing ensures adequate pressure integrity to allow a blowout preventer (BOP) and the drilling riser to be installed. BOPs comprise a system of high pressure valves that prevent water or hydrocarbons from escaping into the environment in the event of an emergency or equipment failure.

The drill bit and string are then lowered through the BOP and into the surface hole. The bit begins drilling at the bottom of the hole, and extra joints are added to the drill string as the drill bit cuts deeper and deeper into the seabed. When a section of well is complete, the drill string is pulled out and the sections of the casing are joined together, lowered into the well, and cemented into place. For this portion of the well, the drilling riser connects the casing set at the seafloor up to the drilling unit, and allows the return of cuttings and drilling muds to the surface drilling unit where processing takes place.

Synthetic-based muds (SBMs) may be used in drilling lower well sections if the use of water-based fluids is technically impractical. Additional information on drill muds and cuttings is provided in Section 2.2.2.5.

A vertical seismic profile (VSP), or check-shot survey, is required for all exploration and delineation wells in the Newfoundland and Labrador and Nova Scotia Offshore Areas (C-NOPB and C-NSOPB 2002a). A VSP is recorded following completion of drilling to get accurate "time-to-depth ties" in a well. This is necessary as seismic data are recorded in time and wells are drilled in metres. The VSP data collection is usually in the final suite of logs, and is undertaken by placing a string of geophones down the well, with a seismic source suspended from the drilling unit. The source may be similar to a seismic survey, but the arrays are usually smaller. The checkshots are typically recorded every 25 to 100 m down the well. In the case of a highly deviated well, operators may place the source on a vessel and follow the trajectory of the well to have the shortest distance between source and receivers. VSPs are

typically acquired using a cluster of medium-sized airguns (with a peak pressure output of approximately 240 to 250 dB re 1 μ Pa @ 1 m) (Davis et al. 1998).

If significant hydrocarbons are found, the well is then evaluated and tested, which may involve formation flow testing. During testing, formation fluids, which may contain hydrocarbons and/or water, flow to the drilling unit. Produced hydrocarbons are separated from produced water on the drilling unit. The amount of produced water potentially encountered during exploration drilling is typically very small in comparison with that during production operations. These small amounts of produced water are sent to the flare, or treated to comply with the Offshore Waste Treatment Guidelines (OWTG) and disposed of offshore. The OWTG specify that production installations that commence operation following publication of these Guidelines (August 2002) should ensure that the 30-day weighted average of oil in discharged produced water does not exceed 30 mg/L and that the 24-hour arithmetic average of oil in produced water does not exceed 60 mg/L (NEB et al. 2002).

Once drilling and any well testing activities are completed, wells are typically abandoned. Cement mixtures or mechanical devices are used to plug the well. The well casing is cut and removed just below the surface of the seafloor and all previously installed equipment is removed. Wellheads are removed from the seafloor, often using a mechanical casing/wellhead cutting device. In the unlikely event that this device fails, operators often use a chemical/directed explosive method to detach the wellhead. If required, the charge is usually set at a minimum of 1m below the sea substrate. A remotely operated vehicle (ROV) is used to inspect the seabed to ensure that no equipment or obstructions remain in place.

2.2.2.3 Associated Activities

Supply vessels and helicopters are used to transport personnel, equipment and supplies to and from a drilling unit. Supply vessels typically make approximately three round trips per week to the drilling unit throughout a drilling program. A dedicated stand-by vessel also attends the drilling unit throughout the operation. Personnel are usually transported to and from the drilling rig by helicopter, with flights taking place approximately four times per week, depending on work schedules, the aircraft used and the distance involved (LGL Limited et al. 2000). Work or activities in support of exploration drilling or seismic surveys in the Laurentian Subbasin will be supported from the relevant jurisdictional area as provided for in the respective *Accord Acts* and approved Benefits Plans.

During drilling operations all other vessel traffic is prohibited from an area around the drill unit as a safety precaution. As specified in the *Newfoundland Offshore Petroleum Drilling Regulations* and the *Nova Scotia Offshore Petroleum Drilling Regulations* (Section 75), this safety zone is usually the greater of either the area within a 500-m radius of the drill unit or, if the unit is anchored, a zone 50 m from the anchor pattern. Notices to Mariners are also issued as part of program management to ensure effective communication regarding equipment, movements and activities.

2.2.2.4 Duration and Timing

Depending on well and water depths and environmental conditions, the drilling of a single exploration well can require 30 to 120 days to complete, and typically takes approximately 45 days. The timing of drilling is often based primarily on rig availability. The particular drilling unit used depends on the water depth involved. Also, some rigs are able to drill year-round in harsh offshore environments, while the operating season of others is more restricted.

2.2.2.5 Emissions And Discharges

The primary potential discharges associated with offshore drilling programs are:

- drill muds and cuttings;
- other liquid wastes (e.g., deck drainage, grey water, etc.);
- solid waste; and
- atmospheric emissions.

Drill Muds and Cuttings

Offshore wells may be drilled using either WBM or a combination of WBM and SBM. The initial drilling phase uses WBM, the primary component of which is seawater, with bentonite (clay) and barite being the primary additives (LGL Limited et al. 2000). The initial portion of a well is drilled without a riser and, therefore, drilling muds and cuttings are discharged directly onto the seabed. WBMs are considered non-toxic, and are therefore approved for direct ocean discharge. Once the riser and BOP are installed, muds and cuttings are returned to the drilling unit.

SBMs are used in drilling wells or portions of wells where the use of water-based fluids is technically impractical. In Atlantic Canada, SBMs typically have been used in high-angle deviated wells (not usually required for exploration and delineation), in well sections where especially problematic formations (e.g., certain shales) are predicted, or in deep-water wells, where they are usually required to prevent the formation of gas hydrates.

SBMs are comprised of a non-toxic synthetic fluid. SBMs must "have a total polycyclic aromatic hydrocarbon concentration of less than 10 mg/kg, be relatively non-toxic in marine environments and have the potential to biodegrade under aerobic conditions" (NEB et al. 2002: 5). SBMs are transported with the cuttings up the riser to the drill rig for recovery and reuse. Once onboard the drilling unit, cuttings are removed from the drilling muds in successive separation stages. Some fluids are reconditioned and reused, while spent SBM is returned to shore for disposal.

Cuttings may be discharged at the drill site provided they are treated prior to discharge with best available treatment technology (defined as a concentration of 6.9 g/100 g or less oil on wet solids as of the time of publication of the OWTG); re-injection during exploration drilling is not technically feasible. This discharge limit may be modified in individual circumstances where more challenging formations and drilling conditions are experienced or areas of increased environmental risk are identified (NEB et al. 2002).

WBMs and/or SBMs are used wherever possible. The use of oil-based mud may be approved only in exceptional circumstances where the use of WBMs and SBMs is not technically feasible, and under no circumstances can whole oil-based mud be discharged. The use of enhanced mineral oil-based mud (EMOBM), for example, may be approved provided its environmental and safety-related performance is demonstrated to be equivalent to or better than SBM (NEB et al. 2002).

The estimated volumes of drill cuttings and WBMs discharged from a single offshore well drilled to a depth of 4,000 to 5,000 m are provided in Table 2.1.

Table 2.1 Estimated Drill Cuttings and Mud Discharged from an Offshore Well Drilled to a Depth of 4,000 to 5,000 m

Cuttings		Whole Mud	
Amount Direct to Seafloor (m ³)	Amount Direct from Rig (m ³)	Amount Direct to Seafloor (m ³)	Amount Direct from Rig (m ³)
273	633	1,617	4,176
Source: LGL Limited et al. (2000: 18).			

For an equal volume of hole drilled, the volume of WBM discharged is typically much greater than for SBM, as SBMs are recycled and not dumped (EPA 1999b, cited in LGL Limited et al. 2000).

Other Discharges

Offshore drilling units routinely produce a variety of other discharges, including:

- grey and black water (e.g., sanitary and food waste);
- ballast water/preload water;
- bilge water;
- deck drainage;
- discharges from machinery spaces;
- cooling water;

- solid waste;
- produced water (well-testing only, typically very small amounts); and
- atmospheric emissions.

The sources and characteristics of these routine discharges and emissions are discussed in detail in LGL Limited et al. (2000). Discharges from offshore drilling rigs must be managed in accordance with the OWTG (NEB et al. 2002), which typically involves treatment of these materials to reduce their hydrocarbon content prior to discharge. Although adherence with these guidelines does not completely preclude the potential for any environmental effect, they do outline recommended practices and standards for the treatment and disposal of wastes from petroleum drilling and production operations in Canada's offshore areas, and for sampling and analysis of waste streams to ensure compliance with these standards. The Guidelines are intended to be the minimum standards to be applied by the Boards in making decisions related to waste treatment, disposal and monitoring. Waste discharged at these concentrations and in the specified manner is, based on current knowledge and experience, not expected to cause significant adverse environmental effects (NEB et al. 2002).

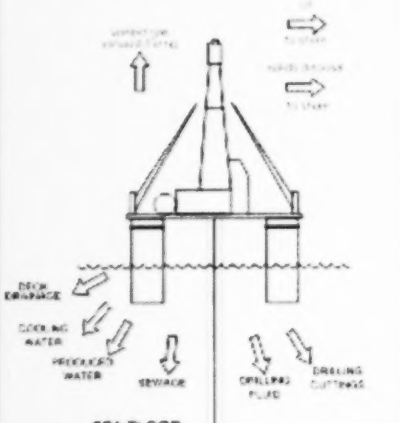
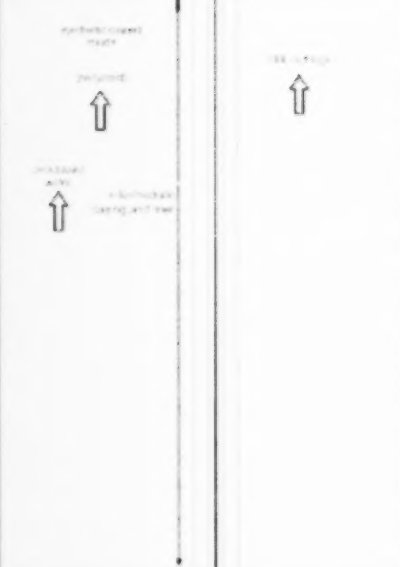
Operational atmospheric emissions may include exhaust from equipment and generators, as well as emissions from the storage and flaring of hydrocarbons associated with well testing (where required). The amount of produced water potentially encountered during exploration drilling is typically very small compared to that during production operations. These small amounts of produced water are sent to the flare, which typically contains a special burner that atomizes the oil and/or gas and water and mixes it with air. This allows for relatively complete combustion and minimizes air pollution (LGL Limited et al. 2000). Flaring, if required at all during exploration drilling, is typically an intermittent and short-term activity only. Any produced water in excess of the flare capacity is treated to comply with the OWTG and disposed of offshore.

Typically, environmental protection plans (EPPs), including a waste reduction plan, are required for exploration projects and address these routine discharges and emissions.

A schematic illustrating the typical emissions and waste discharges associated with an offshore drilling unit is presented in Figure 2.3. A typical drilling mud circulation system is illustrated in Figure 2.4.

All chemicals to be used in drilling programs in the Laurentian Subbasin will be screened through the Offshore Chemical Selection Guidelines (OCSG). These Guidelines are used by industry in making decisions related to the selection of chemicals to be used in offshore drilling and production activities, and to the treatment and disposal of the chemicals selected (NEB et al. 1999). Again, while adherence to the Guidelines does not automatically guarantee the prevention of any environmental effects, the OCSG are intended to provide a consistent framework for chemical selection as part of the environmentally responsible management of chemicals used in offshore drilling and production activities.

Figure 2.3 Conceptual Wellbore, Discharges and Mitigation Measures

ON DECK (Schematic of a semi-submersible drill unit)	DRILLING ACTIVITIES  SEA FLOOR	DISCHARGES 1. deck drainage 2. grey water sewage 3. solids disposal 4. exhaust, vented gas 5. well test burn produced oil 6. drill cuttings disposal 7. produced water (testing only, typically very small amounts)	ENVIRONMENTAL MITIGATION • All contained deck drainage collected and sent to oil/water separator. Oil collected and shipped to shore, released water will meet the 2002 OWTG • Hazardous wastes separated from solid wastes, shipped to onshore facilities • High efficiency igniters minimize atmospheric emissions from vented gas • Drill cuttings discharge at site once oil on cuttings does not exceed 2002 OWTG • Produced water treated to meet discharge criteria
NO RISER SHAFT (Water based drilling muds only)		conductor 1. drill cuttings release surface 2. release of water-based muds	• Without the riser shaft, drill cuttings are not brought to deck, but dispersed from hole using cuttings disposal system • Cuttings will be discharged at the sea-floor around the wellhead • Water based muds are relatively non-toxic in marine environments
WATER-BASED AND/OR SYNTHETIC-BASED DRILLING MUDS		conductor 1. synthetic-based muds recycled 2. drill cuttings release surface intermediate and liner	• Specially designed system is used to reduce oil content on cuttings



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Figure 2.3

CONCEPTUAL WELLBORE, DISCHARGES AND MITIGATION MEASURES

Figure 2.4 Typical Drilling Mud Circulation System

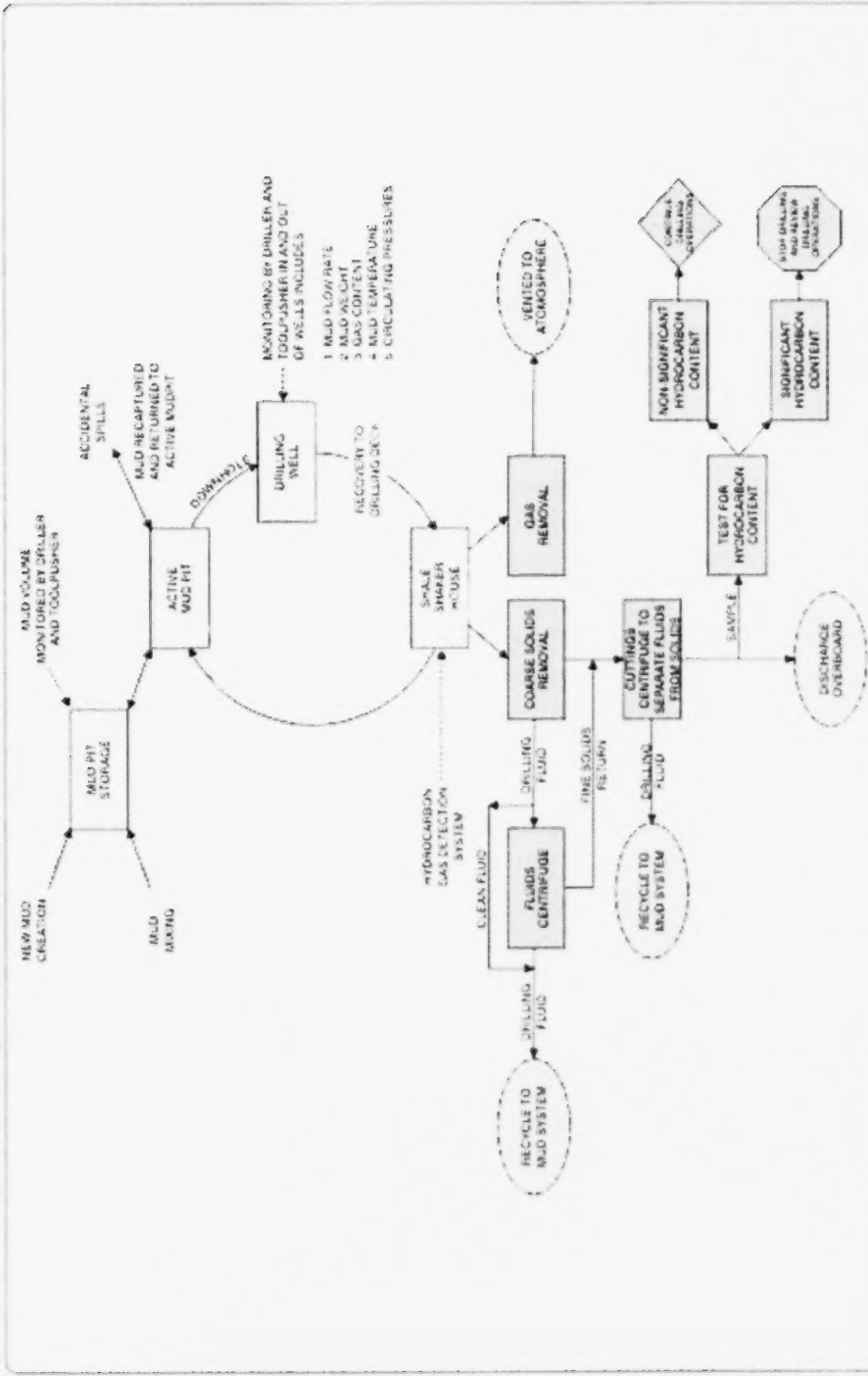


Figure 2.4
TYPICAL DRILLING MUD CIRCULATION SYSTEM

2.2.2.6 Potential Accidental Events

Accidental events that may be associated with offshore drilling programs include subsea and surface blowouts, as well as small platform and vessel fuel spills. The following sections provide a general overview of these potential accidental events.

The potential accidental event of primary concern is a well blowout occurring and discharging oil or gas. There are three basic kinds of offshore petroleum well blowouts (LGL Limited et al. 2000):

Shallow-Water Subsea Blowout: Oil and gas released from a shallow subsea blowout (less than approximately 500 m deep) emanates from a point on the sea bed and rises through the water column to the water surface. Once it reaches the surface, water currents carry the oil down-current and spreads it over the surface, after which the slick moves with the prevailing currents. An example of this kind of blowout was the 1979 *Ixtoc 1* oil blowout in the Bay of Campeche, Mexico.

Deep-Water Subsea Blowout: The gas either converts to solid hydrates or dissolves and does not influence the rise of the oil to the surface. Therefore, the oil is affected by cross currents during its rise, resulting in the separation of the oil droplets based on their size. The large oil drops surface first and smaller drops are carried further down current before reaching the surface. A blowout of this type has never occurred.

Above-Surface Blowout: Oil and gas discharges into the atmosphere from a point on the platform above the water surface, and falls onto the water at some distance downwind. The fate of the oil and gas at this point is determined by atmospheric dispersion processes and the settling velocity of the oil particles. Wind and water current directions affect the ultimate distribution of the oil on the water surface. Examples of this kind of blowout are the 1977 Ekofisk oil blowout in the North Sea and the Uniacke gas/condensate blowout on the Scotian Shelf in 1984.

In addition, the routine transfer and use of fuels and lubricants on drilling platforms and supply vessels can result in small spills into the marine environment.

Probability

The majority of offshore wells are drilled without incident. The probability of a damaging spill occurring as a result of offshore oil and gas operations is very low (LGL Limited et al. 2000).

Compared to other industries that have potential for discharging petroleum into the marine environment, the offshore oil and gas industry has a relatively good record. A study by the US National Academy of Sciences indicates that this sector contributes only 1.5 percent of the total petroleum input to the world's oceans (NAS 1985, cited in LGL Limited et al. 2000). On the US Outer Continental Shelf, over 24,000

wells were drilled and 9 billion barrels of oil and condensate were produced from 1971 to 1995. However, only eight blowouts occurred that involved any discharge of oil or condensate. The total oil discharged in these events was approximately 999 barrels (Husky Oil 2000).

Spills can be categorized into five general groups based on their size (Table 2.2).

Table 2.2 Spill Size Categories

Spill Size Categories	Spill Size Range (in barrels)	Spill Size Range (in m ³ and tonnes)
Extremely Large spills	>150,000	>23,850 m ³ or >20,830 tonnes
Very Large spills	>10,000	>1590 m ³ or >1,390 tonnes
Large spills	>1,000	>159 m ³ or >139 tonnes
Medium spills	50 to 999	7.95 to 158.9 m ³
Small spills	1 to 49.9	0.08 to 7.94 m ³
Source: Husky Oil (2000).		

Historically, only five extremely large spills have occurred in the history of offshore oil drilling, one of which occurred during exploration drilling. A blowout occurred while drilling the *Ixtoc-1* well in 1979 in the Bay of Campeche, Mexico, which lasted for 9.5 months, and spilled 3,000,000 barrels of crude. It was caused by the use of drilling procedures that are not practiced in US or Canadian waters, and which are contrary to regulations and practices within the international oil and gas industry (LGL Limited et al. 2000; Husky Oil 2000). A detailed discussion of the nature and environmental consequences of the *Ixtoc-1* well blowout is provided in NRC (1985).

To date, two blow-outs have occurred offshore Eastern Canada - one at the West Venture N-91 site, and the other while drilling the Uniacke G-72 well. The Uniacke incident started on February 22, 1984, and occurred approximately 17 km northeast of Sable Island. This blowout resulted in the release of natural gas and 240 m³ of condensate, and was controlled in nine days (Cook n.d.; C-NSOPB 1998; Environment Canada n.d.).

In the case of exploration in the Laurentian Subbasin, it is reasonable to expect a very low probability of accidental events, given substantial improvements in offshore technologies and practice in recent years, and the fact that regulatory requirements relating to oil spill prevention in the Canadian offshore are among the most stringent in the world (Husky Oil 2000).

Clearly, the probability of smaller, incidental discharges of hydrocarbons into the marine environment (e.g., fuel spills on drilling platforms) is considerably higher than for larger spills. Hydrocarbon spill statistics for exploration and production activities in the Newfoundland and Labrador Offshore Area from 1997-2001 are provided in table 2.3. Over that period, there were a total of 64 wells drilled in the Newfoundland and Labrador Offshore Area (C-NOPB 2003). From 1997 to 2001, there were 30 spill incidents resulting from exploration drilling programs, ranging from one to 24 spills per year. Of these 30 incidents, 60 percent involved spills of crude oil, 17 percent diesel, 13 percent hydraulic and lubricating oils, and 10 percent involved other oils. The total volume spilled over this five year period was 5,360.42 L (33.7 barrels), of which 49 percent was crude oil, 49 percent was diesel, and the remaining 2 percent were hydraulic, lubricating and other oils. The total volume of hydrocarbons spilled annually during exploration offshore Newfoundland and Labrador ranged from 40 L (0.25 barrels) in 1997 to 3,195 L (20.1 barrels) in 1998. Over that five-year period, spills from exploration drilling accounted for approximately 26 percent of the total number of spill incidents, and comprised less than 20 percent of the total volume of hydrocarbons spilled (Table 2.3; C-NOPB n.d.).

General spill statistics are also provided for the Nova Scotia Offshore Area for the period 2000/2001 to 2002/2003 (Table 2.4). Over that period, there were a total of 67 spill events, ranging from 18 to 25 per year. Of this total, 23 (34 percent) were smaller than 1 L in size, 19 (28 percent) were 1 to 10 L, 19 (28 percent) were 11 to 150 L in size, and 6 (9 percent) were greater than 150 L in size.

Fate and Behaviour

The fate and behaviour of accidental spills are dependent upon site and well-specific characteristics, such as the type and specific properties of the hydrocarbons involved, oceanographic conditions at the well site (e.g., wind and currents), as well as the specific size, location and timing of the spill.

In the case of the Uniacke G-72 blow-out northeast of Sable Island, it is estimated that 75 percent of the condensate evaporated within 24 hours after release. The remainder either formed a temporary surface slick or became entrained in the water column. The surface slick of this light condensate persisted for several days and was observed up to 10 km from the rig. Condensate dissolved in the water presumably persisted longer and travelled further because of reduced evaporation. Measured hydrocarbon concentrations, detected to depths of at least 21 m, were typically less than 100 ppb compared with background levels of about 1 ppb. Biological effects were not observed or evaluated (Boudreau et al. 2001).

Table 2.3 Exploration and Production Hydrocarbon Spill Information, Newfoundland and Labrador Offshore Area (1997 to 2001)

	1997		1998		1999		2000		2001		Total 1997-2001	
	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)
Exploration Drilling												
Synthetic Based Drilling Fluid	0	0	0	0	0	0	0	0			0	0
All Other Hydrocarbons	1	40	4	3,195	24	1,965.42	1	160			30	5,360.42
TOTAL	1	40	4	3,195	24	1,965.42	1	160			30	5,360.42
Development Drilling and Production												
Synthetic Based Drilling Fluid	0	0	2	2,008	9	7,372.1	5	4,700	2	5,600	18	19,680.1
All Other Hydrocarbons	10	1,691	23	593.6	15	1,097.6	4	63.1	14	131.59	66	3,576.89
TOTAL	10	1,691	25	2,601.6	24	8,469.7	9	4,763.1	16	5,731.59	84	23,256.99
Total: Exploration and Production												
Synthetic Based Drilling Fluid	0	0	2	2,008	9	7,372.1	5	4,700	2	5,600	18	19,680.1
All Other Hydrocarbons	11	1,731	27	3,788.6	39	3,063.02	5	223.1	14	131.59	96	8,937.31
TOTAL	11	1,731	29	5,796.6	48	10,435.12	10	4,923.1	16	5,731.59	114	28,617.41

Source: C-NOPB (n.d.).

Table 2.4 General Spills Statistics, Nova Scotia Offshore Area (2000/01 to 2002/03)

Material	< 1 L	1-10 L	11-150 L	> 150 L
2000/2001				
Condensate	-	2	1	-
Synthetic Muds	-	-	3	-
Light Oil	-	4	3	2
Chemicals	-	-	3	-
2001/2002				
Condensate	2	-	-	-
Synthetic Muds	1	1	2	-
Light Oil	10	6	1	-
Chemicals	-	-	-	1
2002/2003				
Condensate	2	2	-	-
Synthetic Muds	1	1	1	-
Light Oil	7	2	4	-
Chemicals	-	1	1	3*
TOTAL	23	19	19	6

Source: C-NSOPB (unpublished).

* The contents of each of the three most recent spills >150 L were: WBM spacer; conduit line fluid, composed of 15% ethylene glycol, 3% lubricant, and the balance of fresh water; and mono ethylene glycol. Two of these spills were between 150 to 160 L.

The behavior and fate of gas and very light crude oil from subsea and surface blowouts was modeled for five representative exploration drilling locations off Nova Scotia and Newfoundland as part of the generic environmental assessment of exploration drilling conducted by LGL Limited et al. (2000). This included two sites within the Laurentian Subbasin study area, one in the Laurentian Channel (408-m water depth) and one on the St. Pierre Bank (98-m water depth). The modeling exercise was based on a condensate flow of 10,000 barrels per day (bpd), and on the physical characteristics of oil from the Cohasset Panuke Project offshore Nova Scotia. Modeling was conducted for each of these sites for subsea and surface blowouts in both winter and summer. Laurentian Channel results were provided for full-gas, half-gas and quarter-gas flow situations to illustrate the potential effect of gas hydrate formation at this 400-m deep site. The results of the spill scenario modeling are summarized in Table 2.5.

For a sub-sea blowout, initial oil slick widths for the St. Pierre Bank site ranged from 3,890 m in summer to 4,024 m in winter. Initial slick widths for the Laurentian Channel site vary according to gas flow situation, and ranged from 3,100 m in winter for a quarter gas-flow situation to 9,420 m for a summer spill at the Laurentian Channel site in a full-gas flow situation. Oil concentrations would drop to 1 ppm within 3.4 to 16 hours, and to 0.1 ppm in 87 to 171 hours. The width of the oil cloud would be between 4.0 to 9.8 km when it reaches 1 ppm and 12.7 to 31.1 km when it reaches 0.1 ppm (Table 2.5).

Table 2.5 Blowout Characteristics

Site	Season	Initial Slick Width (m)	Initial Slick Thickness (µm)	Slick Survival Time (hr)	Initial Disp Oil Conc. (ppm)	Time to 1 ppm (hr)	Cloud Width at 1 ppm (m)	Km to 1 ppm	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (m)	Km to 0.1 ppm
Sub-Sea Blowouts											
St. Pierre Bank	Winter	4,024	24	.01	2.0	16	5,700	10	122	18,000	90
	Summer	3,890	24	.01	1.8	13	5,200	2	110	16,500	35
Laurentian Channel (Full Gas)	Winter	4,920	12	.00	1.1	3.4	5,300	1	102	16,700	50
	Summer	9,420	12	.00	1.1	3.6	9,800	1	171	31,100	100
Laurentian Channel (Half Gas)	Winter	3,900	15	.00	1.4	6.6	4,600	1	94	14,400	45
	Summer	7,480	15	.00	1.3	8.5	8,400	1	156	26,700	75
Laurentian Channel (Quarter Gas)	Winter	3,100	20	.01	1.7	9.3	4,000	1	87	12,700	40
	Summer	5,930	20	.01	1.5	12.7	7,300	1	143	23,000	65
Surface Blowouts											
St. Pierre Bank	Winter	290	143	.17	13.7	10.1	1,073	5	35.4	3,395	31
	Summer	270	108	.20	10.2	7.9	860	1	28.8	2,728	5
Laurentian Channel	Winter	290	88	.10	8.5	7.4	846	1	28.0	2,676	11
	Summer	270	133	.25	12.6	9.0	959	2	32.0	3,032	5
Source: LGL Limited et al. (2000: 207, 211).											
Note: The modeling exercise was based on the physical characteristics of oil from the Cohasset Panuke Project offshore Nova Scotia. The behavior of any spill would depend on the specific nature of the hydrocarbons spilled, as well as site-specific oceanographic conditions.											

For a surface blowout (assumed to occur at 25 m above the water surface), the modeling predicted that initial slick widths would range from 270 m in summer to 290 m in winter for both the St. Pierre Bank and Laurentian Channel sites. Oil concentrations would drop to 1 ppm within 7.4 to 10.1 hours, and to 0.1 ppm in 28.0 to 35.4 hours. The width of the oil cloud will be between 0.846 to 1.073 km when it reaches 1 ppm and 2.676 km to 3.395 km when it reaches 0.1 ppm (Table 2.4).

Spill trajectory modelling for each site indicated that oil clouds from the St. Pierre Bank site would generally move to the northwest, while a spill at the Laurentian Channel site would move south and then southwest. The modelling exercise indicated that spills would disperse well before reaching land (LGL Limited et al. 2000).

The potential environmental effects of any such accidental events are discussed in Chapter 5.

Again, the fate and behaviour of accidental spills are dependent upon site and well-specific characteristics, such as the type and specific properties of the hydrocarbons involved, oceanographic conditions at the site, as well as the size, location and timing of the spill. Environmental assessments for individual proposed drilling programs in Atlantic Canada typically include an analysis of oceanographic conditions at the drill site and modelling studies of the fate and behaviour of hypothetical oil spills.

2.2.3 Past and Potential Exploration in the Laurentian Subbasin

The Laurentian Subbasin is thought to have petroleum resource potential, and some exploration has occurred in the area. Although no drilling has taken place to date, there have been a number of seismic surveys undertaken in the region in recent years, including one in 2002, two in 2001, two in 1999 and one survey in 1998. Although outside of the study area for this SEA, seismic surveys and drilling have also occurred within the French Corridor surrounding the islands of St. Pierre and Miquelon (see Section 3.3.2).

The conversion of existing federal exploratory permits into *Accord Act* exploration licences by the C-NOPB and C-NSOPB will permit application by the operators for approval to drill exploration or delineation wells. Future seismic and other geoscientific surveys are also likely to occur in the area.

In consideration of the size of past exploration licences and the size of the permit area being considered for conversion to licences, it may be assumed for the purposes of this SEA that there could be a maximum of 15 exploration licences issued if the full permit area is converted. Under the Boards' rights issuance processes, licences must be relinquished if a well is not spudded within the first period of the licence (typically five years). The current level of information available on the resource potential of the area does not permit an exact prediction of the number of exploration wells likely to be drilled during the period of these licences.

The following estimate is used for planning purposes without attempting explicitly to take into account the area's resource potential. Since the mid-1980s, approximately 75 percent of exploration licences that have expired or were relinquished in the Newfoundland and Labrador Offshore Area did not have a well drilled on the licence. It is uncertain whether this historical average would apply to licences arising from the permit conversion process in the Laurentian Subbasin.

Further, historical experience in the Newfoundland and Labrador Offshore Area indicates that (to the end of 2002), 23 significant discoveries have been made as a result of 129 "wildcat" exploration wells - a proportion of approximately 18 percent, or 1 in 5.5. Of these discoveries, four to date (Hibernia, Terra Nova, White Rose and the potential Hebron development) have attracted more than one delineation well - approximately 3 percent of exploration wells, or 1 in 32. Full pre-development field delineation offshore Newfoundland and Labrador to date has involved seven to nine wells in addition to the initial

discovery well; this drilling typically has extended considerably beyond the nine-year period of the original exploration licence.

In the Nova Scotia Offshore Area, a total of 192 wells have been drilled (or are in the process of being drilled) to date. Of those, approximately 111 have been "wildcat" exploration wells, with the remainder being delineation wells, development wells (either for Panuke-Cohasset or the Sable Offshore Energy Inc. (SOEI) development), and/or service relief wells. There have been 23 discoveries from these wildcat exploration wells, for a success rate of approximately 20.7 percent.

Recent experience with exploratory drilling offshore Eastern Canada indicates that operators prefer to share the high mobilization costs of drilling units and to drill their respective prospects sequentially rather than simultaneously. Due to the small number of units world-wide that are capable of drilling deep-water prospects in harsh environments, one unit may be dedicated to the deepwater portions of the permit area and another selected for on-shelf portions.

In consideration of the above, it is assumed for the purposes of the SEA that five to seven exploration wells will be drilled during the period of the exploration licences, and that one discovery is made that attracts three further delineation wells during the nine-year licence period - for a total of eight to ten wells during the period of the licences. It is further assumed that no more than two drilling units will be active at any given time, and that for a fraction of the drilling time two pairs of wells "overlap".

It is anticipated that there may be approximately two seismic program applications for the Laurentian Subbasin in 2003, and possibly three in 2004. As of June 2003, one proposed seismic survey has been approved for the Newfoundland and Labrador portion of the region. In addition, as of that time, one seismic survey was being undertaken in the Nova Scotia Offshore Area just south of the Laurentian Subbasin, and a further seismic program is being proposed for 2003 which may overlap slightly with the western portion of the study area. Due to the limited number of seismic vessels, operators often coordinate their seismic programs to share a vessel when it is in the area. Therefore, surveys tend to be undertaken sequentially in a given region, rather than concurrently (C-NSOPB 2002). However, the specific number, location, timing and extent of surveys which may be undertaken in the Laurentian Subbasin in the future cannot be predicted.

As stated previously, the SEA focuses upon the "exploration phase" of offshore petroleum activity in the Laurentian Subbasin. It includes consideration of all of the components and activities which may be associated with potential seismic surveys and well drilling programs in the region, as described earlier in Chapter 2. The potential for, and nature of, offshore oil and gas production activity in the Laurentian Subbasin will depend on the results of seismic surveys and drilling programs in the region. The likelihood, location and timing of any possible offshore oil and gas development activity in the region is unknown and cannot be predicted at this point.

3.0 EXISTING ENVIRONMENT

The following sections provide an overview of the existing environment of the Laurentian Subbasin, including its physical, biological and socio-economic environments. This description is based upon existing, readily available information gathered through a review of the published literature, unpublished reports, and other relevant information sources.

3.1 Physical Environment

3.1.1 Physiography

The major physiographic features of the study area are the St. Pierre Bank and Laurentian Channel (Figure 3.1). The St. Pierre Bank is the most western of the four banks which comprise the Grand Banks of Newfoundland, and has a total area of approximately 13,750 km². The surface of the bank is relatively flat, with a water depth of approximately 30 m at its shallowest point. Halibut Channel lies to the east of St. Pierre Bank, and separates it from Green Bank. The Laurentian Channel extends from the St. Lawrence River Valley through the Gulf of St. Lawrence, across the continental shelf between Nova Scotia and Newfoundland, and terminates at the shelf edge. The channel's sides are relatively straight, and it has an average width of nearly 100 km and a water depth of approximately 540 m at its deepest point (Fader et al. 1982). The Laurentian Channel separates Banquereau and the eastern Scotian Shelf from the Grand Banks of Newfoundland. Water depths reach 3,000 m in the southern portion of the study area, increasing dramatically as the continental shelf falls away.

3.1.2 Marine Geology

The bedrock geology of the study area is comprised primarily of Tertiary and Late Cretaceous rocks (King and MacLean 1976). Surficial formations found in the study area include: Emerald Silt; Sambro Sand; LaHave Clay; and Sable Island Sand and Gravel (King 1970; Fader et al. 1982).

The surficial geology of the St. Pierre Bank is comprised of Sable Island Sand and Gravel, a clean reddish to greyish-brown, fine to coarse-grained, well-sorted sand that grades locally to coarse, well-rounded gravel with some large boulders. Sand deposits are confined primarily to the eastern and southeastern areas of the bank, and gravel occurs along its central and western portions. Sambro Sand, a dark, greyish-brown fine to coarse grained sediment with some silt and clay-sized particles, fringes the bank and nearshore areas and occurs along the edge of the Laurentian Channel. The seabed along the Laurentian Channel itself is comprised of LaHave Clay, a homogeneous marine mud (primarily clayey silt). Emerald Silt, a proglacial clayey and muddy silt, overlies a portion of the channel (Fader et al. 1982) (Figure 3.2).

Figure 3.1 Marine Physiography

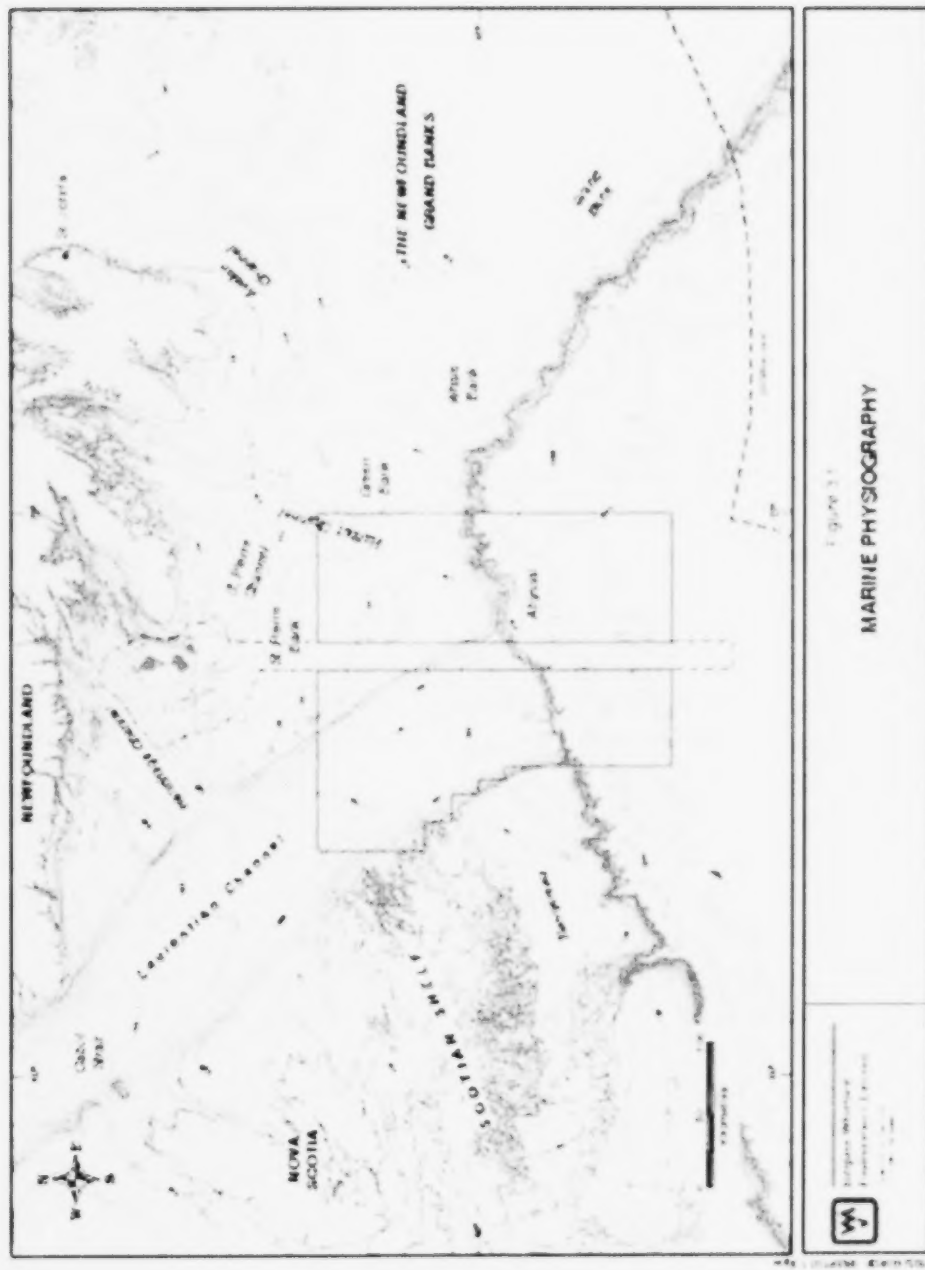
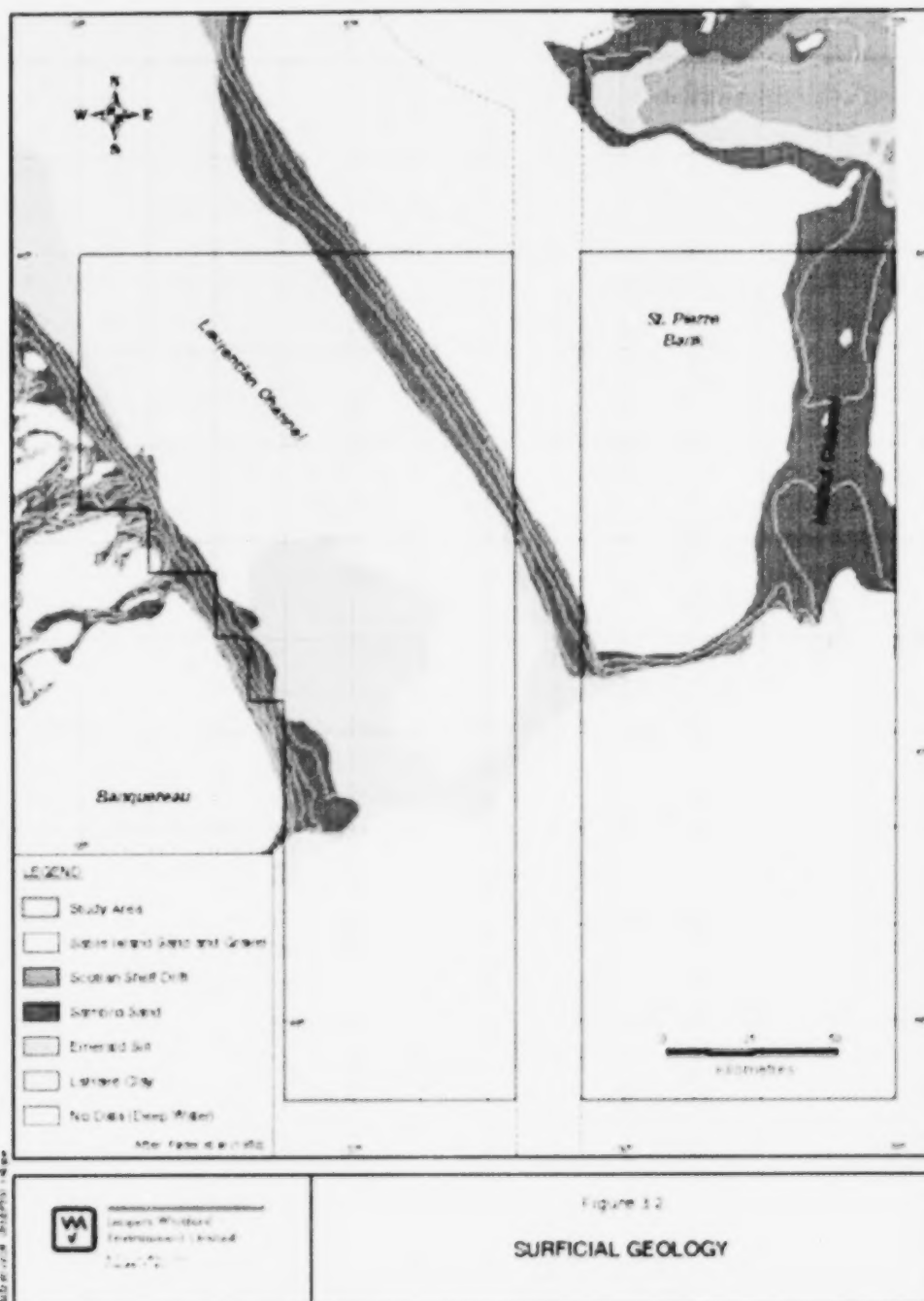


Figure 3.2 Surficial Geology

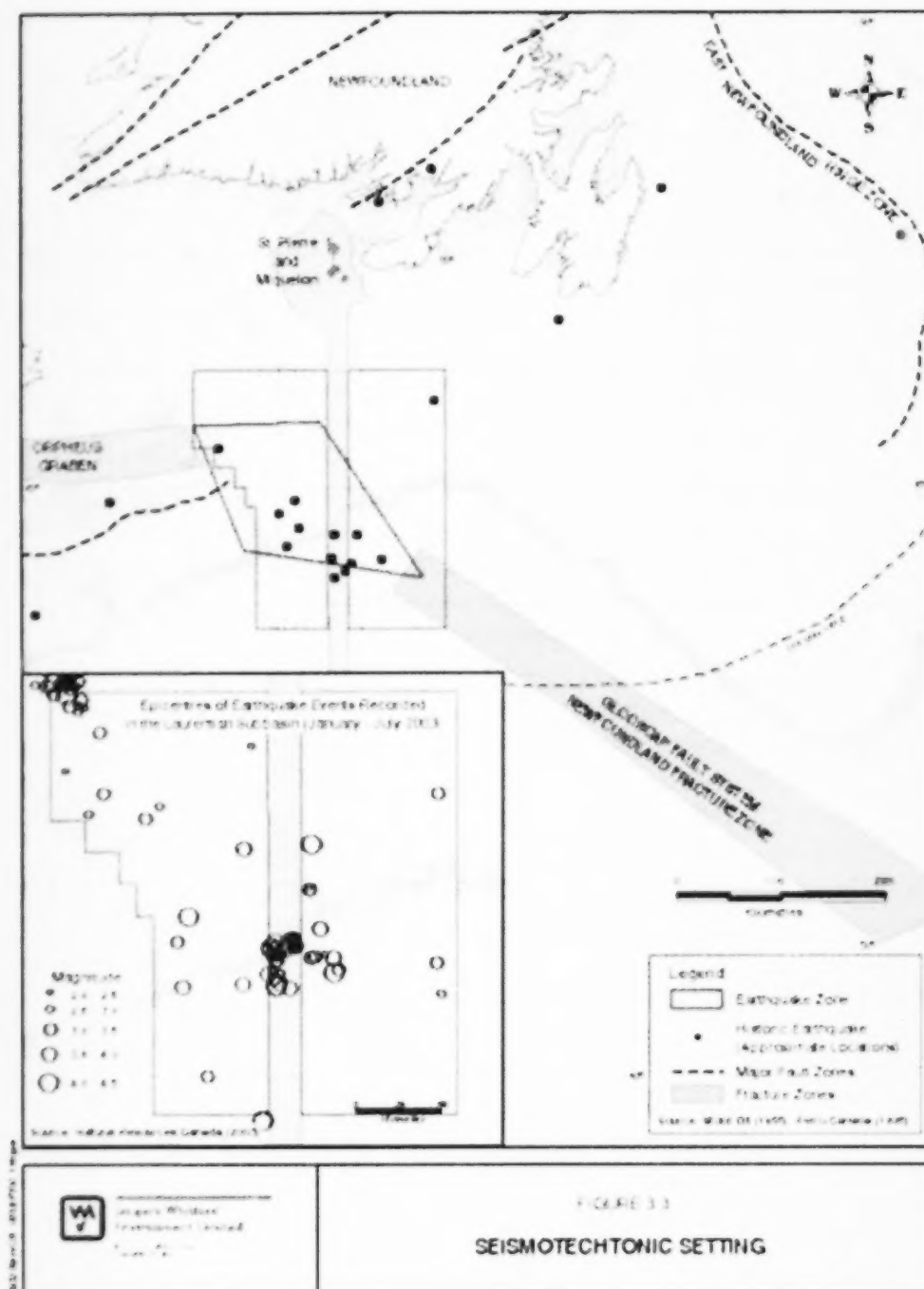


The Laurentian Channel is located along the Newfoundland Fracture Zone (Figure 3.3), and is generally regarded as the most seismically active portion of the Newfoundland Continental Shelf (Petro-Canada 1995). There have been a number of earthquakes recorded in this area. Most of these have occurred in the Laurentian Slope Seismic Zone, located at the southern end of the channel, and are thought to be associated with the Glooscap Fault portion of the Newfoundland Fracture Zone (Seaconsult 1988, cited in Husky Oil 2000).

The largest earthquake occurred in November 1929, and had a magnitude of 7.2, with aftershocks having magnitudes as high as 6.0. This earthquake resulted in undersea telegraph cables being severed at various locations, and generated a large tsunami (seismic sea-wave) that resulted in considerable destruction and loss of life on Newfoundland's Burin Peninsula (Trifunac et al. 2002). The epicentre for the 1929 earthquake was at 44.69°N and 56.00°W, in the southern portion of the Laurentian Subbasin (Dewey and Gordon 1984, cited in Trifunac et al. 2001) (Figure 3.3). Earthquakes with magnitudes of approximately 6.0 also occurred in the same general area in 1951, 1954 and 1987 (Seaconsult 1988, cited in Husky Oil 2000). The approximate locations of the epicentres for a number of earthquakes which occurred between 1929 and 1980 are illustrated in Figure 3.3 (Mobil Oil 1985; Petro-Canada 1995). However, past seismic events are not well documented for the offshore, particularly for earthquakes with magnitudes of less than 5.0 (Seaconsult 1988, cited in Petro-Canada 1995).

Earthquake information for the period 1980 to present is available from the National Earthquake Database (Natural Resources Canada 2003). The approximate locations of the epicentres for those recorded within or immediately adjacent to the Laurentian Subbasin area over the 1980 to present period are illustrated in Figure 3.3. From January 1980 to July 2003, there were 57 events recorded within the boundaries of the region (including the portion of the French Corridor within it, see Figure 3.3). However, the magnitudes of these earthquake events have been relatively low, ranging from 2.1 to 4.5, with an average magnitude of 3.12 and a median of 3.1. The most recent event occurred on May 19, 2003 (having a magnitude of 2.1, the lowest recorded over the period). As illustrated in Figure 3.3, the epicentres of the majority of these recorded events were in the south-central portion of the study area, with an additional concentration at and immediately adjacent to the northwestern edge of the region (see Natural Resources Canada (2003) for additional information on the dataset).

Figure 3.3 Seismotectonic Setting



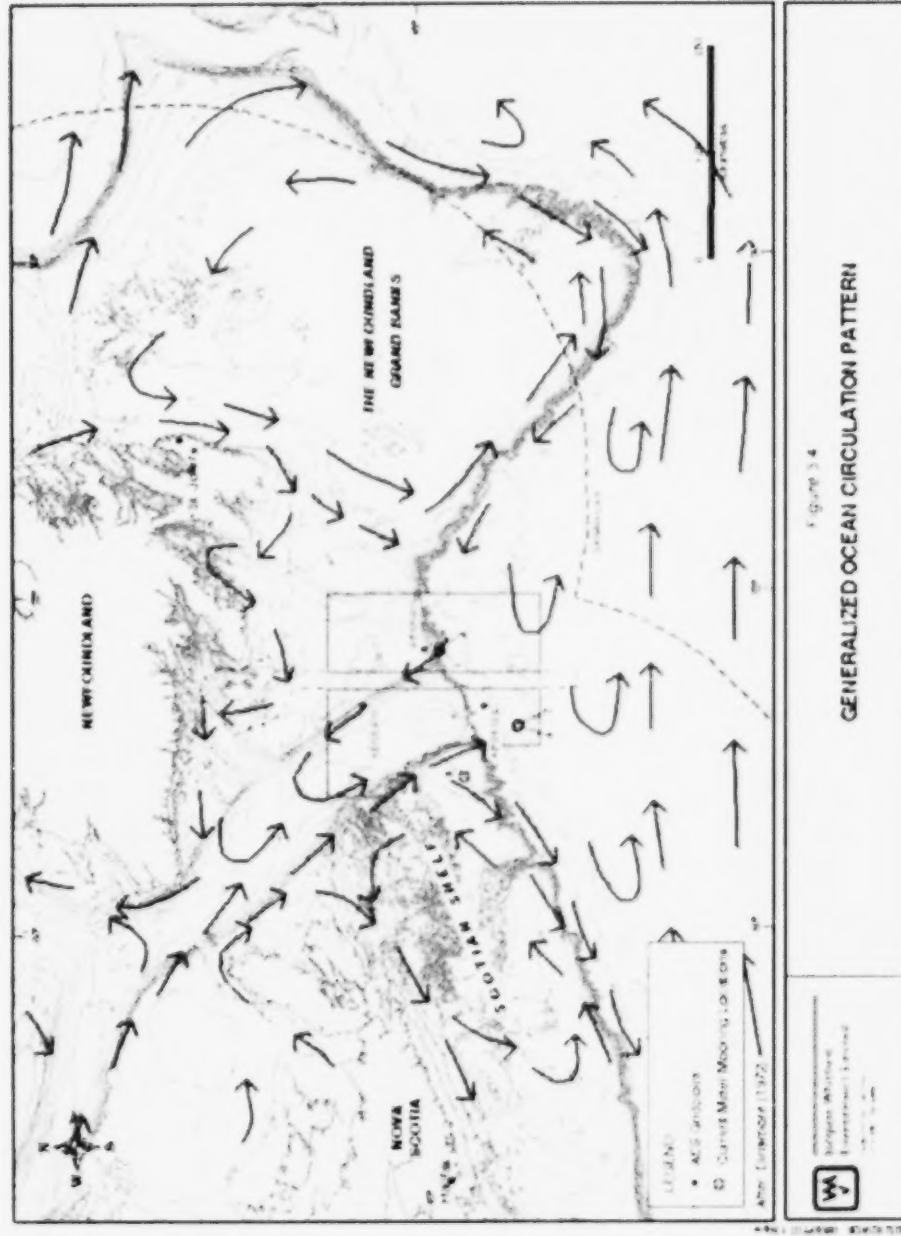
3.1.3 Currents

Water circulation in the area is influenced primarily by the waters of the Labrador Current, which flows south along the east coast of Newfoundland, and divides into two segments at approximately 50°N latitude. Most of the current is diverted offshore and along the eastern edge of the Grand Banks and south through the Flemish Pass. The inshore branch flows in a southwesterly direction through the Avalon Channel and along the south coast of Newfoundland. Petrie and Anderson (1983) estimated that approximately 10 percent of the Labrador Current follows this inshore path. This branch then divides into two parts, one flowing west around the north shore of St. Pierre Bank, and the other flowing south between Green Bank and Whale Bank. Additionally, part of the offshore branch of the Labrador Current flows around the tail of the Grand Bank, westward along the continental slope (where it may interact with the Gulf Stream and slope water), to the Laurentian Channel and into the Gulf of St. Lawrence (Colbourne 2002). The primary current systems which influence water circulation in the Laurentian Subbasin region are illustrated in Figure 3.4. The tidal influence in this area is also important, and locally reverses the direction of flow (Dinsmore 1972; Fader et al. 1982).

Current data are available from moored current meters for several locations within or adjacent to the study area (Bedford Institute of Oceanography 2003a) (see Figure 3.4). Data are, for example, available for two sites directly within the Laurentian Subbasin (Sites 1 and 2), located over the shelf in the southeast portion of the study area. Both are in the same general location, and together provide current data for each month of the year (1996-1997) at four depths ranging from 50 to 680 m. At 50 m, mean monthly current speeds in this area ranged from 0.073 m/s (April) to 0.334 m/s (June). At 150 m, average monthly current speeds in this area ranged from 0.038 m/s (May) to 0.192 m/s (November), while at 680 m, mean currents ranged from 0.003 m/s (June) to 0.041 (May). Maximum current speeds at 50 m at that location ranged from 0.307 m/s (May) to 0.822 m/s (December) (Appendix B).

Current data for these and several other sites in the general region are provided in Appendix B. Additional information on current patterns in the general region can be found in a number of other sources (e.g., Drozdowski et al. 2002; Dupont et al. 2002; Han 2000; Han et al. 1997; 1999; 2002; Loder et al. 1997; Petrie and Anderson 1983; Petrie et al. 1987).

Figure 3.4 Generalized Ocean Circulation Pattern



3.1.4 Waves

The wave climate is an important consideration in the design of offshore structures and operational planning. Key parameters for describing wave conditions are significant wave height and maximum wave height. The significant wave height is the average height of the highest one-third of all waves in a given period. Its value roughly approximates the characteristic height observed. The maximum wave height is the greatest vertical distance between a wave crest and adjacent trough, and provides an indication of extreme wave conditions.

Wave statistics for the general area (1958 to 1999), from the AES40 dataset, are provided in Tables 3.1 and 3.2. The data are for the "Banquereau Region", an approximately 80,000 km² area which includes the Laurentian Subbasin (33,440 km²) (Atlantic Climate Centre 2003).

Mean monthly wave heights in the area range from 1.8 m (July and August) to 3.6 m (January). Maximum wave heights range from 6.2 m (July) to 13.7 m (October).

Table 3.1 Significant Wave Heights: Monthly Data Statistics (1958 to 1999)

	Mean (m)	Std Dev (m)	Median (m)	Maximum (m)	Minimum (m)	95% UL (m)	95% LL (m)	Most Frequent Directions	Number of Readings
January	3.6	1.6	3.3	12.7	0.0	6.5	1.6	W	88,502
February	3.3	1.6	3.1	12.1	0.0	6.0	1.3	W	80,648
March	2.9	1.6	2.7	12.5	0.0	5.8	0.2	W	88,536
April	2.6	1.2	2.4	10.5	0.0	4.7	1.0	W	85,680
May	2.0	0.9	1.9	9.2	0.0	3.7	1.0	SW	88,536
June	1.9	0.7	1.7	6.6	0.3	3.2	0.9	SW	85,680
July	1.8	0.6	1.7	6.2	0.0	2.9	0.9	SW	88,536
August	1.8	0.6	1.7	9.6	0.3	3.0	0.9	SW	88,536
September	2.2	0.9	2.0	9.1	0.3	3.7	1.0	SW	85,680
October	2.5	1.1	2.3	13.7	0.3	4.6	1.3	W	88,536
November	3.0	1.3	2.8	11.7	0.8	5.5	1.4	W	85,680
December	3.5	1.5	3.2	12.2	0.4	6.2	1.6	W	88,536

Source: Atlantic Climate Centre (2003).

Table 3.2 Wave Period: Monthly Data Statistics (1958 to 1999)

	Median (sec)	Maximum (sec)	Minimum (sec)	95% UL (sec)	95% LL (sec)	Number of Readings
January	6	14	5	10	5	88,254
February	6	14	5	10	5	77,941
March	6	14	5	10	5	81,214
April	5	12	5	8	5	84,189
May	5	12	5	8	5	88,524
June	5	10	5	6	5	85,680
July	5	10	5	6	5	88,527
August	5	12	5	6	5	88,536
September	5	12	5	8	5	85,680
October	5	14	5	8	5	88,536
November	6	14	5	10	5	85,680
December	6	14	5	10	5	88,536

Source: Atlantic Climate Centre (2003).

Wave extreme data are also available for various individual gridpoints in the region from the AES40 dataset. Return period extremes for three sample points within or immediately adjacent to the Laurentian Subbasin (see Figure 3.4) are provided in Table 3.3.

Table 3.3 Wave Extreme Data for Three AES Gridpoints (1958-1997)

Return	AES Grid Point 5470 Lat. 45.6250 N, Long 56.6667 W		AES Grid Point 5400 Lat. 45.0000 N, Long 55.8333 W		AES Grid Point 5324 Lat. 44.3750 N, Long 56.6667 W	
	HSig (m)	Hmax (m)	HSig (m)	Hmax (m)	HSig (m)	Hmax (m)
2	9.95	18.55	10.39	19.54	10.47	19.64
5	10.60	19.69	11.08	20.74	11.15	20.89
10	11.03	20.44	11.54	21.53	11.60	21.72
20	11.45	21.16	11.97	22.30	12.04	22.52
40	11.85	21.87	12.40	23.05	12.46	23.30
50	11.98	22.10	12.54	23.29	12.60	23.55
100	12.39	22.80	12.96	24.03	13.02	24.32

HSig – Maximum Significant Wave Height.
Hmax – Maximum Individual Wave Height.
 Data are for 1958-1997 combined: GUMBEL Distribution.
 See Figure 3.4 for gridpoint locations.
 Source: AES40 North Atlantic Wave Reanalysis – Extremal Analysis (Oceanweather Inc. 2003).

3.1.5 Wind

Wind is also a major consideration in planning offshore structures and operations. The prevailing winds affecting the ocean off southern Newfoundland are relatively high compared to other marine areas of Atlantic Canada, and exhibit seasonal variations (Hardy Associates 1985). Wind speed and directional information for the area (1958 to 1999), from the AES40 dataset, are provided in Table 3.4 and 3.5. The data are again for the Banquereau Region, an approximately 80,000 km² area which includes the Laurentian Subbasin (33,440 km²) (Atlantic Climate Centre 2003).

Winds in the region are predominantly from the west, with average monthly wind speeds ranging from 11 knots (20.4 km/h) in July to 20 knots (37.0 km/h) during the December to February period. Maximum wind speeds range from 42 knots (77.8 km/h) in June to 62 knots (114.8 km/h) in January.

Table 3.4 Wind Speed: Monthly Data Statistics (1958-1999)

	Mean (kts)	Std Dev (kts)	Median (kts)	Maximum (kts)	95% UL (kts)	95% LL (kts)	Most Frequent Directions	Number of Readings
January	20	8.4	20	62	35	8	W	88,502
February	20	8.2	19	53	34	7	W	80,648
March	18	8.2	18	57	33	6	W	88,536
April	16	7.4	15	47	29	5	W	85,680
May	13	6.5	12	47	25	3	SW	88,536
June	12	5.7	11	42	22	3	SW	85,680
July	11	5.2	11	46	20	3	SW	88,536
August	12	5.4	12	46	21	4	SW	88,536
September	14	6.2	13	51	25	5	SW	85,680
October	16	7.1	16	57	28	6	W	88,536
November	18	7.7	18	52	32	7	W	85,680
December	20	8.2	20	54	34	8	W	88,536

Source: Atlantic Climate Centre (2003).

Table 3.5 Percent Frequency of Occurrence of Wind Speed (1958-1999)

	Wind Speed Class (kts)						Most Frequent Directions	Number of Readings
	>0 - 9	10-19	20-33	34-47	48-63	≥ 64		
January	9.3	39.2	44.6	6.8	0.1	-	W	88,502
February	10.5	41.9	42.0	5.5	0.1	-	W	80,648
March	14.3	44.7	36.8	4.0	0.1	-	W	88,536
April	22.7	49.2	26.8	1.3	-	-	W	85,680
May	35.5	50.4	13.8	0.3	-	-	SW	88,536
June	37.9	53.0	9.0	0.1	-	-	SW	85,680
July	39.4	54.9	5.6	0.1	-	-	SW	88,536
August	34.9	56.9	8.2	0.1	-	-	SW	88,536
September	26.3	55.8	17.5	0.4	-	-	SW	85,680
October	18.0	50.5	30.0	1.3	0.1	-	W	88,536
November	12.1	45.3	39.3	3.2	0.0	-	W	85,680
December	9.7	40.1	44.1	6.0	0.1	-	W	88,536

Source: Atlantic Climate Centre (2003).

3.1.6 Other Aspects of Marine Climate

In addition to wind, other aspects of marine climate such as fog and freezing precipitation are also important considerations in planning for and implementing offshore exploration programs. Fog develops primarily when warm, moist air from the south interacts with the cold and, at times ice-infested, waters of the North Atlantic. Fog may occur in all seasons, but is typically most frequent in the spring and summer, when the temperature difference between the sea and air is greatest. Canadian climate normals data for St. Lawrence (located on Newfoundland's Burin Peninsula, approximately 100 km north of the study area) for 1971 to 2000 indicate 131.5 days with fog per year in the area. The average number of fog days per month ranges from 5.4 days (December and February) to 21.6 days in July, with fog occurring most frequently in the May to August period (Environment Canada 2003). Fog conditions offshore can be hazardous for shipping and for drilling operations, particularly when icebergs are present (Section 3.1.8). In addition, St. Lawrence also receives freezing rain or drizzle an average of 12.8 days per year, with most occurring in March (3.8 days per year), February (3.2 days per year) and January (2.6 days per year) (Environment Canada 2003). Considerations related to the potential effects of meteorological conditions on offshore exploration activity in the study area are discussed further in Section 5.5.

3.1.7 Water Temperature and Salinity

Water temperature and salinity determine the density of seawater, which in turn influences oceanic circulation and mixing (Mobil 1985). The near-bottom portion of the water column in the Laurentian Subbasin region consists of two distinct oceanographic regimes. One is influenced by cold, fresh water from the eastern Newfoundland Shelf, which includes much of St. Pierre Bank and areas to the east. In this region temperatures generally range from 0 to 2°C, but are often less than 0°C in many years. The other regime includes the deeper regions of the Laurentian and Hermitage channels and areas to the west of St. Pierre Bank. This region appears to be influenced mostly by warmer shelf slope water from the south (Colborne et al. 2002).

Water temperature summary data are available for several hydrographic subareas which comprise the Laurentian Subbasin (i.e., St. Pierre Bank (Subarea 62); Laurentian Channel (Subarea 65)). Bedford Institute of Oceanography (2003b) provides an overview of seawater properties in the study area. Average monthly surface water temperatures over the St. Pierre Bank range from -0.06°C in February to 15.44°C in August, with water temperatures at 100-m depth ranging from 0.04°C in August to 1.17°C in May. In the Laurentian Channel, average surface water temperatures range from 0.17°C (March) to 16.02°C (August). At 100-m depth, average water temperatures range from 0.62°C (November) to 2.44°C (September), while at 400 m, mean monthly temperatures range from 4.83°C (September and November) to 5.37°C (March) (Bedford Institute of Oceanography 2003b) (Table 3.6).

Table 3.6 Mean Monthly Water Temperatures at Select Water Depths – St. Pierre Bank and Laurentian Subbasin

Water Depth (m)	Mean Water Temperature (°C)											
	J	F	M	A	M	J	J	A	S	O	N	D
St. Pierre Bank (Subarea 62)												
0	1.52	-0.06	0.14	1.10	3.41	6.83	11.58	15.44	13.90	10.62	7.46	4.88
50	1.21	-0.09	0.18	0.47	1.94	1.63	2.04	1.99	2.55	2.85	4.12	3.08
100	0.70	0.19	0.24	0.33	1.17	0.22	0.25	0.04	0.88	-0.21	0.61	0.26
Laurentian Channel (Subarea 65)												
0	1.05	0.21	0.17	1.37	3.70	6.71	12.09	16.02	13.52	10.32	6.82	5.14
50	1.36	0.48	0.31	0.99	1.64	1.58	2.08	2.00	3.12	2.81	3.69	4.21
100	1.51	1.06	1.27	1.57	2.05	1.39	1.37	1.32	2.44	0.86	0.62	1.89
200	5.41	5.22	5.50	6.04	5.68	5.81	5.68	6.14	5.09	5.86	5.02	5.26
300	5.66	5.97	5.79	5.71	5.44	5.22	5.29	5.71	5.59	6.03	5.52	5.94
400	5.09	5.25	5.37	5.05	5.02	4.87	4.94	5.07	4.83	4.97	4.83	5.04
Note: Temperature - Salinity Climatologies are based on data from the Bedford Institute of Oceanography's Climate Database.												
Source: Bedford Institute of Oceanography (2003b).												

An overview of long-term average water temperature and salinity conditions on the banks and channels which comprise the study area (for the spring period) is provided by Colbourne (2000; 2002). Over the St. Pierre Bank, average water temperatures range from 1°C near the bottom to 2°C near the surface and 1 to 2°C beyond the shelf edge in the upper 100 m of the water column. In the deeper waters of the channels and on the continental slope, water temperatures generally range from 2°C at approximately 125 to 150 m depth, to 5 to 6°C near the bottom. The average bottom temperature for April in the Laurentian Channel is approximately 5°C. On the St. Pierre Bank, bottom temperatures range from 0°C on the eastern side to 2 to 3°C on the western portion of the bank. In general, the bottom isotherms follow the bathymetry around the Laurentian Channel and the southwestern Grand Banks, decreasing from 2°C at approximately 200 m depth to 5°C below approximately 300 m (Colbourne 2000; 2002).

Over the St. Pierre Bank, water salinities in April generally range from 32.5 psu near the bottom to 32.1 psu near the surface. In the deeper channel waters and on the continental slope region, salinities increase from 33 psu at 130 m to 34.5 psu near bottom. On the slopes of the St. Pierre Bank in water depths of 100 to 300 m, salinities generally range from 33 to 34.5 psu (Colbourne 2000; 2002).

Detailed information on water temperature and salinity in the hydrographic subareas which comprise the Laurentian Subbasin (i.e., St. Pierre Bank (Subarea 62) and the Laurentian Channel (Subarea 65)) is available at Bedford Institute of Oceanography (2003b), including static and animated contour maps and vertical sections illustrating spatial and seasonal change in water temperature and salinity in these regions.

3.1.8 Ice

Sea ice is produced when the surface layer of the ocean freezes. Icebergs are produced when ice from glaciers that have extended to the coast break off and enter the ocean (Mobil 1985). Portions of the Newfoundland and Labrador and Nova Scotia Offshore Areas are susceptible to seasonal intrusions of ice.

Sea ice off Newfoundland and Labrador typically does extend as far south as the study area, although the maximum extent of this ice extends into the eastern portion of the Laurentian Subbasin. The maximum extent of the Gulf of St. Lawrence ice edge also reaches the western portion of the Laurentian Subbasin (Petro-Canada 1995; Husky Oil 2000; Drinkwater et al. 2001). The Canadian Ice Service (2001) provides information on the 30-year frequency of sea ice in the region (1971 to 2000). The potential for ice is generally greatest in March, when there is up to a 34 to 50 percent frequency of ice extending into the western part of the study area. Ice conditions can vary considerably from year to year. In recent years, for example, warmer than normal temperatures resulted in less ice than normal off Newfoundland and Labrador and in the Gulf of St. Lawrence (DFO 2000a; 2001a). In the Gulf of St. Lawrence in 2000, for example, sea ice disappeared much earlier than normal, with little or no ice reaching the Scotian Shelf (Drinkwater et al. 2001). However, in 2003, sea ice extended further south and persisted longer than has been the case in recent years. Detailed ice information for the general region is available from the Canadian Ice Service (2001; 2003).

Icebergs off Newfoundland and Labrador originate primarily from the glaciers of West Greenland. Most icebergs initially move northward, during which time they melt, fracture and subdivide, with many becoming grounded in the shallow waters off western Greenland. Those icebergs that eventually reach the Newfoundland coast flow southward with the Baffin Current and Labrador Current (Husky Oil 2000).

Icebergs are relatively uncommon in the study area. The International Ice Patrol (IIP) maintains a database of iceberg activity in the North Atlantic (between 40° and 52°N latitude, 39° to 57°W longitude). Between 1983 and 2001, there were only 229 icebergs sighted within the study area (east of 57°W longitude). The number of icebergs sighted per year for this period ranged from 0 to 107, with a mean of 14 sightings annually (NSIDC 2002). In comparison, the average number of icebergs reaching the Grand Banks each year is approximately 900 (NSIDC 2002; Husky Oil 2000). Information on the sizes of the icebergs sighted in the study area from 1983 to 2001 is provided in Table 3.7.

Table 3.7 Iceberg Size Classes and Distribution (1983 to 2001)

Iceberg Size Class	Number of Sightings in the Laurentian Subbasin (1983-2001)
Growler (Less than 15 m in length)	67
Small (15-60 m in length)	29
Medium (60-122 m in length)	40
Large (greater than 122 m in length)	16
Undetermined	77
Total Iceberg Sightings	229
Source: NSIDC (2002).	

Of the 229 icebergs sighted in the study area during the 1983 to 2001 period, most (119 sightings, 52 percent) occurred in June, with 23.1 percent in May, 12.2 percent in April, 6.6 percent in July, 5.2 percent in March and 0.9 percent in February (NSIDC 2002).

3.1.9 Noise Environment

Background noise in the ocean can originate from a range of natural and anthropogenic sources (Urick 1983), including oceanic turbulence, thermal noise, surface wave action, natural seismic disturbances, biological activity and shipping traffic. Above 500 Hz, deep ocean ambient noise is primarily the result of wind and wave conditions. At sound frequencies less than 500 Hz (including that in the range of airgun emissions, typically 20 to 120 Hz), shipping noise is an important factor (Davis et al. 1998).

Urick (1983) gives values for oceanic waters equivalent to peak-to-peak noise levels of 75 to 95 dB re 1 μ Pa, depending upon proximity to shipping lanes. For deep, oceanic waters (greater than 200 m depth) distant from shipping lanes, a value of 95 dB re 1 μ Pa may be assumed (Richardson et al. 1995), but considerably higher levels will occur closer to shipping lanes. More variable in character is the ambient noise in shallow, continental shelf waters (less than 200 m), especially in coastal bays and harbours, where there is concentrated human activity. The main sources here are shipping and industrial noise, wind noise and the biological noise generated by marine mammals and other biota. Typical peak levels of ambient noise range from 110 to 120 dB re 1 μ Pa in shallow water (less than 200 m) (Richardson et al. 1995), depending on oceanographic conditions and shipping and other human activity. Therefore, background value of 110 dB re 1 μ Pa is a reasonable assumption for shallow, continental shelf waters (although this value is very much dependent upon frequency, with noise levels at higher frequencies typically less).

As a result of natural conditions and existing marine activities, the marine environment of the Laurentian Subbasin is likely already quite noisy. Ambient noise is an important consideration in determining the potential effects of the noise generated by seismic surveys and drilling operations in the marine environment (e.g., in some circumstances, background noise may mask the effects of these sound

sources). Although there is a lack of direct, detailed information on background noise levels in the Laurentian Subbasin, some information is available for the general region.

A study of the background noise field around Sable Bank, for example, was completed by Defence Research Establishment Atlantic in 1999 (Heard et al. 1999). Additional data for the area of the Sable Bank, the Gully and the Laurentian Channel collected in 1998 were analyzed and merged with these previous datasets by Desharnais and Collison (2001). The 1998 data include mean noise levels for a site in the southern portion Laurentian Channel at various frequencies. The data indicate overall mean noise levels ranging from 104.6 at 20 Hz to 81.6 at 1,000 Hz (the wind noise-dominated band). The main features at this site were a 10-dB increase of noise levels at 20 Hz (compared to those at 30 Hz) due to finback whales, and the approximately 95 dB re $1\mu\text{Pa}^2/\text{Hz}$ at 80 Hz due to shipping. The shipping noise recorded was limited in bandwidth, with little observed outside the 60 to 80 Hz band (a radar survey indicated that no ships were within 75 nautical miles of the site), and was likely from long-range shipping in the deeper water elsewhere in the channel. Acoustic propagation through the channel effectively filters out the low-frequency component of the shipping noise. It was found that these values fit well with previous analyses (Desharnais and Collison 2001).

3.2 Biological Environment

The following sections provide an overview of the existing biological environment of the study area, including information on plankton, benthos, fish, marine birds, marine mammals and sea turtles. Again, this overview description is based on existing, readily available information on the environmental setting of the study area. The scientific names of all species discussed are provided in Appendix A.

3.2.1 Plankton

The plankton includes those organisms that are carried by water currents, including micro-organisms, algae, juvenile and adult invertebrates, and fish eggs and larvae.

3.2.1.1 Phytoplankton and Primary Production

Nutrients such as nitrates, phosphates and silicates dissolved in the water are used by phytoplankton for primary production. Directly or indirectly, phytoplankton species are the food supply for zooplankton, fish, marine birds and mammals. Phytoplankton is the foundation of the marine food web. Due to upwelling along the slopes of the offshore banks and channels, the study area is very productive year-round (Breeze et al. 2002).

In the North Atlantic ocean, there is a strong seasonal variation in primary production. The abundance of phytoplankton generally peaks in the spring, when light levels increase (the spring bloom), and to a lesser extent in fall. The spring bloom may vary from year to year in terms of duration and intensity. It

may occur at low intensity from March to June or may occur as a sudden, short peak (Pomeroy et al. 1991). The increased light levels during the spring warms the surface waters to a depth of approximately 10 to 20 m. The thermocline, combined with intense grazing by zooplankton and exhaustion of nutrient supply, results in a mid-summer low in primary production. As the thermocline weakens in the fall, upwelling increases, causing an influx of nutrients into the photic zone, resulting in a second, fall phytoplankton bloom (Pinet 1992).

A Continuous Plankton Recorder (CPR) has been used to collect plankton samples in the North Atlantic since 1959. The CPR is towed by commercial and weather ships along standard travel routes, collecting phytoplankton and zooplankton samples. Data collected by the CPR between 1959 and 1992 were analyzed by Myers et al. (1994, as cited in Breeze et al. 2002). Diatom species usually dominate the spring peak, while the fall peak is usually dominated by dinoflagellates (Myers et al. 1994). Although the water column has a high nutrient concentration, during the winter primary production is low due to low light intensity (Pinet 1992).

An indication of spatial and temporal variation in primary productivity in the waters off Newfoundland and Labrador and Nova Scotia are illustrated in a number of representative maps provided in Appendix B. In the study area, productivity typically peaks in June, while the lowest productivity usually occurs during December (Appendix B). Semi-monthly composite images of primary productivity in the area (1997 to present) are available through the Bedford Institute of Oceanography (2003c).

Physical oceanographic conditions and dynamics have a profound effect on the distribution, abundance and growth rates of phytoplankton, and studies have shown clear evidence of spatial variation in phytoplankton biomass and productivity based on oceanographic conditions (Mobil 1985). Waters over the edge of the continental shelf, for example, are often highly productive because of upwelling where nutrients are brought to the surface, allowing a higher abundance of plankton. Surveys conducted by Mobil in the early 1980s indicated that the western edge of the St. Pierre Bank, for example, is an area of high biomass and enhanced primary productivity (Mobil 1985; Petro-Canada 1995). Areas and seasons of high productivity are critical locations and times for spawning and feeding fish, birds and marine mammals.

3.2.1.2 Zooplankton/Ichthyoplankton/Nekton

Zooplankton are an important link in the transfer of energy between phytoplankton and fish in the marine food web. Zooplankton in the Northwest Atlantic are dominated by copepods (Myers et al. 1994), whose populations increase sharply in the spring as they feed on the abundant phytoplankton. Zooplankton populations decline as they are grazed in summer, but usually rise again in the fall. The magnitude and duration of the fall peak is less than in the spring. Again, zooplankton may be expected to peak in areas of upwelling along the channel slopes and the western edge of the St. Pierre Bank. Within the Laurentian Channel common species include the euphausiid krills *Meganyctiphanes*

norvegica and *Thysanoessa* species (White and Johns 1997) and *Calanus* copepods. *Calanus* copepods in particular are an important prey for whales and are concentrated in the Laurentian Channel (see Section 3.2.5.1). *M. norvegica* is also abundant within the study area along the southeastern slope of Banquereau Bank (Sameoto and Cochrane 1996, as cited in Breeze et al. 2002).

Copepods may be the most abundant zooplankton species, but hyperiid amphipods, chaetognaths and euphausiids also make up a considerable portion of the zooplankton biomass. Zooplankton biomass may vary by at least 2.5 times in consecutive years (Anderson and Dalley 1997). Furthermore, spatial variation can be higher than temporal variation (Dalley et al. 1999). Zooplankton abundance also varies diurnally; they are more abundant at the surface at night than during the day, especially over deeper water (Hays 1996).

Ichthyoplankton are the eggs and larvae of fish, which drift in the water column. Species commonly found on the St. Pierre Bank during the spring include the eggs of yellowtail flounder, sand lance, cod, witch flounder and haddock, and American plaice larvae and eggs. During late summer and fall, the predominant ichthyoplankton species are the larvae of capelin, yellowtail flounder, witch flounder, cod and American plaice. Many of the same species are common on the slope area west of St. Pierre Bank, except that redfish are much more abundant in this area in spring (Mobil 1985). Eggs and larvae of cod, haddock, pollock, scallop (including deep-sea and Iceland) and silver hake have been identified, on the outer banks of the Scotian Shelf including the Banquereau Bank. However, there is very low larval fish diversity on Banquereau Bank and in the Laurentian Channel (Breeze et al. 2002). Species spawning on Banquereau Bank include cod, herring, winter and thorny skate, witch flounder, Atlantic halibut, Stimpson's surf clam, and snow crab (C-NSOPB 2003). Although most species undergo a daily vertical migration, ichthyoplankton tend to be distributed near, or above, the thermocline in surface waters (Husky Oil 2000).

3.2.2 Benthos

Marine benthos are those plants and animals that live in or on the sea bottom. Benthic animals form an important food source for many species of fish. Shellfish also comprise an increasingly important part of the fishery in Atlantic Canada, and some species are of considerable economic value.

Existing information on benthos within the study area is sparse and dated. Stewart et al. (2001) provide a compilation of existing information on marine benthos on the eastern Canadian continental shelf, slope and adjacent areas. Of the various sources identified, only two past studies occurred within the Laurentian Subbasin. Nesis (1965) describes data collected from Soviet research surveys in 1959 and 1960, and Russian commercial fishing in 1954 and 1958 to 1960. Sampling stations for these programs were established along transect lines (however, the quality of diagrams in the report is too poor to discern the total number of station locations or habitat classifications). Hutcheson et al. (1981) selected four biological sampling stations on the Grand Banks and 10 stations in the Hibernia field. One of these

stations was at the north end of St. Pierre Bank. No species list was included in the report; therefore a complete inventory of benthic animals is not available. Photos of bottom types present in the study area are provided in Fader et al. (1982) and MacLean and King (1971) (Figure 3.5).

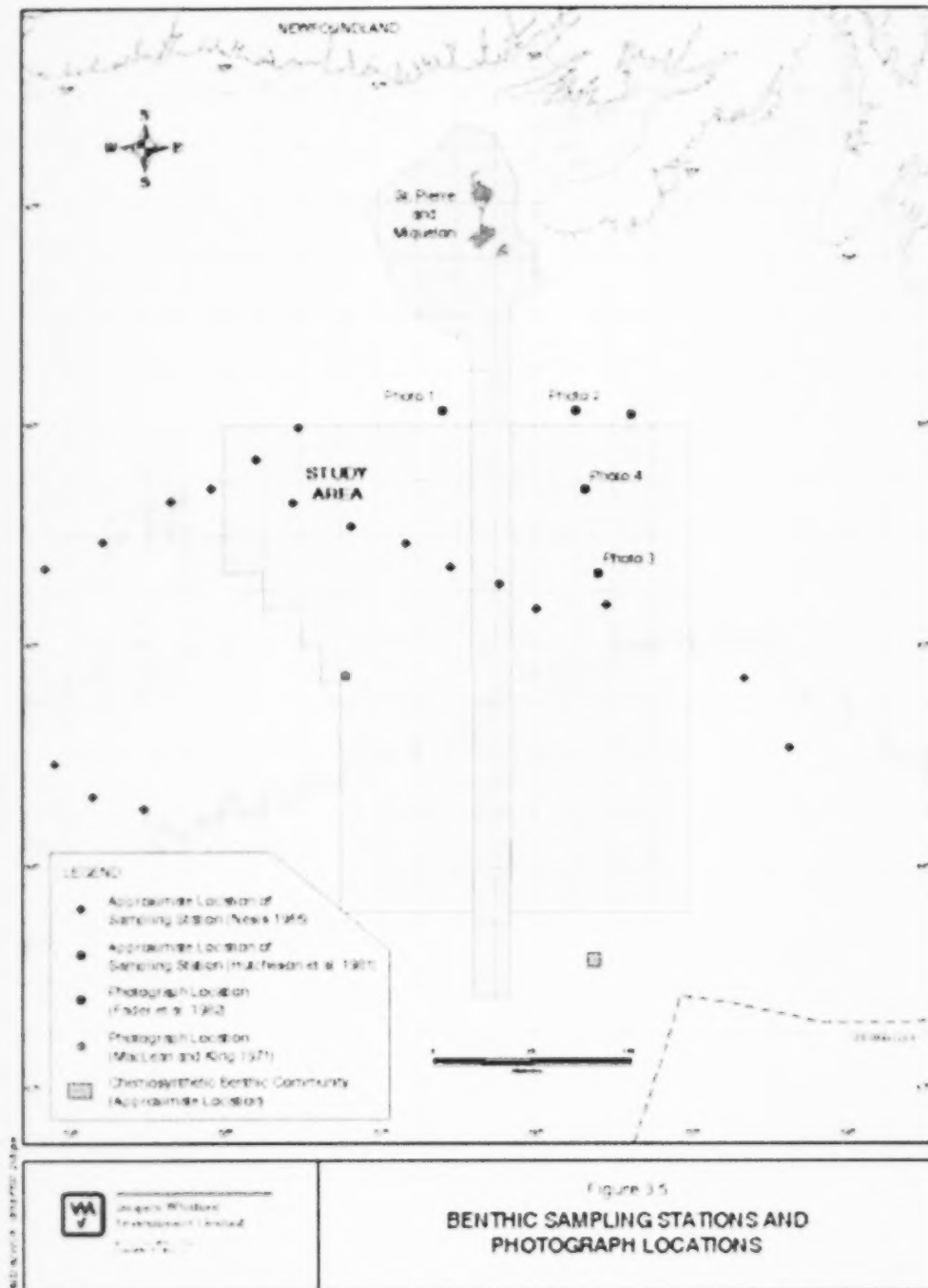
Water depths within the Laurentian Subbasin range from 30 m to greater than 3,000 m. This indicates the potential presence of a variety of benthic communities, depending on substrate, depth, current, temperature, and nutrients. According to Nesis (1965), the distribution of the benthos in the study area is determined by the water masses and substrate type. Bank waters occur down to 50 to 60 m depth. From 50 to 60 m to 90 to 100 m is a zone of mixing of bank and Labrador waters. From 90 to 100 m to 225 to 250 m the Labrador waters dominate. From 225 to 250 m to 340 to 360 m is a zone of mixed Labrador and sub-arctic waters. Deep waters of the Laurentian Trough and Cabot Strait occupy the depths below 250 to 470 m. Hutcheson et al. (1981) classify benthic species down to 50 m as boreal. At 90 to 250 m Arctic species dominate, with a few boreal species. Phytoplankton constitute practically the only primary food source for bottom fauna and the phytobenthos is important to benthic animals on St. Pierre Bank where at depths of 45 to 65 m, undergrowths of *Ptilota* sp. and other red algae occur.

3.2.2.1 Grand Banks - St Pierre Bank and Eastern Scotian Shelf - Banquereau Bank

Benthic Habitats and Communities

The ecological communities of the western and eastern boundaries of the study area are characterised as *Echinarrhynchus parma*-*Ammodytes americanus* (sand dollar - sand lance) habitat. As can be deduced from their names, the sand dollar and sand lance are normally found on sandy substrates. The sand lance buries itself in the sand to hide, while the flat sand dollar browses slowly over the surface. Both of these species are important food sources for commercial fish and shellfish.

Figure 3.5 Benthic Sampling Stations and Photograph Locations



The sea bed of the shallow St. Pierre Bank (45 to 55 m) is composed of stones, shingle, shells well encrusted with *Lithothamnium* (a coralline alga) (Nesis 1965). This type of habitat on the western St. Pierre Bank is shown in Photo 1.



Photo 1 Bottom photograph of the Sable Island Sand and Gravel, pebble to boulder-size material on western St. Pierre Bank at 42 m depth (Fader et al. 1982: 33)

Hutcheson et al. (1981) described a sand-gravel mixture with finer substrates on top of the banks at depths of 45 to 100 m. Other types of benthic habitat on the St. Pierre Bank at depths of 48 to 60 m that are not described by either Nesis (1965) or Hutchenson et al. (1981) is shown in Photos 2 to 4.



Photo 2 Sable Island Sand and Gravel habitat of very fine well sorted sand on the east-central area of St. Pierre Bank at a depth of 64 m (Fader et al. 1982: 35). (Note numerous burrows and likely bivalve siphons)



Photo 3 Sable Island Sand and Gravel habitat of well sorted fine gravel and shell hash (*Mya* sp.) on southeastern St. Pierre Bank at a depth of 48 m (Fader et al. 1982: 36)

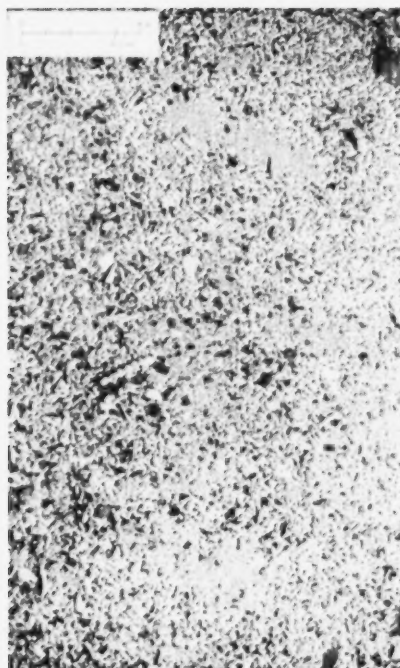


Photo 4 Sable Island Sand and Gravel habitat in an area of sand with minor fine gravel and broken shell material at the southeastern corner of St. Pierre Bank at a depth of 60 m (Fader et al. 1982: 37)

The biomass in the habitat sampled by Hutchenson et al. (1981) at the St. Pierre Bank station averaged 432 g/m^2 , including sand dollar (334 g/m^2), sand lance (76 g/m^2) and sea urchin (12 g/m^2). Of the top 10 species, polychaetes (eight species) were the dominant taxonomic group, in particular *Exogone hebes* (syllid worm), with an average density of 220 individuals/ m^2 . The echinoid *Ophiura robusta* (dwarf brittle star) was also found. *Hyas araneus* (toad crabs), *Chionoecetes opilio* (snow crab) and *Mesodesma deauratum* (wedge clam) were also present. Other crustaceans were shrimp, amphipods, isopods and cumaceans. Suspension feeders or surface deposit-feeders and detritivores were the predominant species. The total number of species found at that site is unknown, as a species inventory list is not available.

Nesis (1965) reported benthic animals including *Cucumaria frondosa* (orange-footed sea cucumber), *Ophiopholis aculeata* (daisy brittlestar), *Strongylocentrotus droebachiensis* (green sea urchin), bryozoans, hydroids, *Thelepus cincinnatus* (terebellid worm), *Spirorbis* spp. and *Balanus crenatus* (crenate barnacle). The standing crop was dominated by molluscs (51.6 g/m^2) and echinoderms (190.8 g/m^2), followed by barnacles (21.6 g/m^2), polychaetes (7.7 g/m^2), others (2.9 g/m^2), crustaceans (2.6 g/m^2) and nematodes (0.1 g/m^2). Polychaetes were numerically dominant followed by crustaceans. Benthic colonial organisms, including bryozoans, hydrozoans, sponges, and corals, greatly contribute to the complexity of marine habitats. These types of habitats are typical nursery grounds for juvenile fish

and invertebrates, due to protection from predators. These types of sessile colonial organisms serve to increase the biodiversity of the benthos (Henry et al. 2002).

E. parma, *S. droebachiensis* and *Ophiura sarsi* (notched brittle star) communities occur as a bordering ring around all banks at a depth of 95 to 220 m, (average depth: 146 m) (Nesis 1965). The sediments tend to be sandy or silty sand. The mean biomass of benthic community in this habitat was 149 g/m², comprised of 89 g/m² of *E. parma*, 10 g/m² of *S. droebachiensis*, 9 g/m² of *Ophiura sarsi* and *Astarte borealis* (mollusc). *O. aculeata* (daisy brittle star), *Onuphis conchylega* (polychaete), byrozoa, *T. cincinnatus* and *Macoma calcarea* (chalky macoma) contributed 2 to 4 g/m² of biomass.

There is a transition zone between 225 and 250 m into the *Brisaster fragilis* (spatangoid heart urchin) communities described in the benthic habitats and communities in Section 3.2.2.2.

The benthos of the southeastern corner of Banquereau Bank is similar to the benthos of the St. Pierre Bank. It is composed of two separate communities: *Echinarachnius parma* (sand dollar)-*Ammodytes americanus* (sand lance) community, and *Modiolus modiolus* (horse mussel)-*Ophiopolis aculeata* (brittlestar) community.

The sand dollar-sand lance community is found on sandy substrates at depths of 95 to 220 m, along the eastern and southern edges of Banquereau Bank (SOEP 1996, as cited in LGL 2000). Species typical of this community type include sand dollars, sand lance, *Arctica islandica* (ocean quahog), *Mactromeris polynyma* (Stimpson's surf clam), *Cyrtodaria siliqua* (northern propellor clam), *Ophiura* sp. (brittle stars), polychaete species (e.g., *Spiohanes bombyx*), and various amphipod crustaceans (e.g., *Ampelisac macrocephala* and *Pricillina armata*) (Breeze et al. 2002). The species in this community are important forage species for commercial fishes and invertebrates (snow crab) on Banquereau Bank.

The horse mussel-brittlestar community is typically found at greater depths than the sand dollar community, on coarse substrates (Breeze et al. 2002). This community is found in the southeastern corner of the Banquereau Bank (SOEP 1996, as cited in LGL 2000). Typical species of this community include horse mussels, brittlestars, several families of polychaetes (Sabellidae, Terebellidae, and Maldanidae), amphipod crustaceans (*Erichthonius fasciatus*, *Unicola* sp.), and encrusting coralline algae (Breeze et al. 2002). Bordering the southern and eastern slopes of Banquereau Bank, adjacent to the horse mussel-brittle star community, is a community consisting mainly of horse mussels and rhodophytes (red algae) (SOEP 1996, as cited in LGL 2000).

The eastern slope of Banquereau Bank, leading to the Laurentian Channel, contains a basket star (*Gorgonocephalus arcticus*) community. Most of this area is known as the Stone Fence, a very productive fishing area populated by large corals. This community is found on coarse substrate in water depths of 200 to 1,500 m.

Sediment Quality

Existing information on sediment quality information within the Laurentian Subbasin is also extremely limited and dated. Hutcheson et al. (1981) also collected sediment samples for chemical analyses (reported in MacKnight et al. 1981), with hydrocarbon and total organic carbon (TOC) analyses performed at a single sampling station on the St. Pierre Bank. TOC at the St. Pierre Bank sample station was 1.45 percent, high compared to the mean TOC value on the Grand Banks of 0.17 ± 0.16 percent. Hydrocarbons measured as "oil equivalents" of 5 ng/g and 471 ng/g as n-alkanes at the St. Pierre Bank station were found. The concentrations of hydrocarbons found on the Grand Banks ranged from non-detectable to 223 ng/g oil equivalents. However, in general there is very little in the way of available, current sediment quality information for the Laurentian Subbasin area.

3.2.2.2 Laurentian Channel

Benthic Habitats and Communities

Bottom communities of the Laurentian Channel have been characterised as *Brisaster fragilis*-*Ctenodiscus crispatus*-*Amphiura otteri*-*Pennatularia* habitat. *Brisaster* is a genus of deep water spatangoid, heart urchin. Burrowing in sand and mud, spatangoids have adapted to this lifestyle by having specialized spines, fascioles, and petaloids. They are sediment swallowers with no need for an Aristotle's lantern. *C. crispatus* (mud sea star), is a deposit feeding echinoderm. *A. otteri* is a species of deep-sea brittlestar and *Pennatularia* is in the octocoral order of sea pens and is adapted to live in soft substrates (Photo 5).



Photo 5 Soft mud with sand in the Laurentian Channel at a depth of 443 m (MacLean and King 1971) (Note sea pen, burrows and worm tubes)

This benthic community type is found in the Cabot Strait and Laurentian Channel at depths below 250 m. The substrate consists of clay-silt and at the edge of depressions, sandy silt. The biomass is approximately 35 g/m², *B. fragilis*, *C. crispatus* and *A. otteri* each having a mean biomass of about six g/m². *Astarte crenata whiteavesi* (a bivalve), *Lumbriconereis* spp. (mostly *L. fragilis*) (thread worms), and *Kophobelemnion stelliferum* (sea pen) are approximately 1.5 to 3 g/m².

This habitat is characterised by warm water species and an absence of cold water forms. The low diversity in the fauna is attributed to the soft bottom, unfavourable habitat for epilithic species.

Deep-Sea Corals

The generic term coral refers to stony corals (scleractinians), sea anemones (actinarians), soft/leather corals (alcyonaceans), horny corals (gorgonaceans) and sea pens (pennatulaceans). Twenty-seven species are known to occur in Atlantic Canada (Mukhida and Gass 2001). Deep-sea corals are found at depths of 200 to 1,500 m. To date, most observations of deep-sea corals by Department of Fisheries and Oceans (DFO) have been limited to depths of 500 m. Some data for deeper areas have come from DFO groundfish surveys and local fishers.

Depending upon species, corals form colonies (reefs) or are solitary; some can be metres tall while others are only a few centimetres. It is the gorgonacean corals that have captured the interest of scientists and the public. Some have large branching forms similar in shape to tropical corals, and may take hundreds of years to grow; fishers often refer to these specimens as "trees".

Potential habitat locations for deep-sea corals include areas of upwelling, or other areas, where nutrient concentrations are high and there is a suitable hard substrate for attachment. Some coral species develop on mud substrates. The walls of canyons, ridges or bank edges with exposed hard substrate offer the highest potential for coral growth. The walls of the Laurentian Channel may have exposed rock outcrops that would be suitable for coral (Breeze et al. 1997). Litvin and Rvachev (1963) reported lime corals and fragments along the southern edge of St. Pierre Bank and areas of the Grand Banks and Flemish Cap. Fishers report corals on the southern edge of St. Pierre Bank and the southwest side of the Grand Banks (Gass 2002). Dillon et al. (2003) observed deep water corals in the upper slope mixed-bottom community (200 to 1,200 m) in the general vicinity of the study area; the observed corals were small and none of the surveyed sites contained dense patches of corals. Below 1,000 m, corals were observed at low densities and frequencies at surveyed sites (Dillon et al. 2003). Boulders and cobbles are also known to be important substrates for corals. Gorgonian corals, for example, the most abundant corals in other areas of Atlantic Canada, settle out and grow only on large boulders (Breeze et al 1997). Little research has been conducted on deep-sea corals in Atlantic Canada, and their distribution is not well known.

The ecological importance of deep-sea corals is that they provide a habitat for a diverse benthic community. Polychaetes, amphipods, sponges, barnacles, bryozoans, ophiroids, and larval and adult fish are found in association with corals. Corals create heterogeneous habitats, and are important locations for protecting juvenile fish from predators. The corals also provide habitat to invertebrates, an important food source for bottom-dwelling fishes. As a result, coral areas are often targeted by fishers for the redfish, pollock, halibut and shrimp that aggregate there (Breeze et al. 1997).

DFO first conducted coral surveys at the Stone Fence area, a submerged terminal moraine located on the southwestern side of the Laurentian Channel along the shelf break of Banquereau Bank (see Section 3.2.7) in 2000 (MacIsaac et al. 2001). In the summer of 2002, researchers at the Bedford Institute of Oceanography conducted another study, including video surveys, of deep-sea corals along the Stone Fence (D. Gordon, pers. comm.) and identified *Lophelia pertusa* at that time (F. Scattolon, pers. comm.). Fishermen had reported coral in commercial bottom trawl catches on the Stone Fence in 366 to 914 m of water. An area surveyed in 2003 covered the mouth of the Laurentian Channel. A deep-water *Lophelia pertusa* reef of approximately 1,000 m by 500 m was identified. The reef, located at a depth of 260 to 400 m, is a complex of several closely located coral mounds with large amounts of dead, skeletal debris and live, broken colonies (most observed between 300 and 320 m) (F. Scattolon, pers. comm.).

This species has been studied extensively in Norway where it was found in reef formations 25 m high and is known to support higher densities of invertebrate megafauna (including commercial species) than soft bottom habitats. Other corals found along the Stone Fence included *Paragorgia arborea*, *Acanthogorgia*, *Keratoisis ornata*, and *Primnoa resedaeformis* (MacIsaac et al. 2001). Footage from the 2002 survey is currently being analyzed and should be available in early 2004.

3.2.2.3 Abyssal

Nesis (1965) sampled one station in 2,150 m of water on the southwestern part of the Grand Bank. Representative organisms included: *Ophiomusium lymani* (brittlestar); *Porcellanaster caeruleus*; *Bathybiaster robustus* and *Pontaster forcipatus* (the starfishes); *Pourtalesia wandeli* (the sea urchins); *Ypsilothuria talismani* (sea cucumbers); *Pennatulula prolifera* (feather star); *Dentalium solidum* and the shells of empty of this tusk shell; *Scaphander* (a gastropod); *Lumbriconereis* spp. (the thread worm); and *Phascolion* (Sipunculids).

Crustaceans such as isopods, amphipods, tanaids and cumaceans are common in the deep sea and may make up 30 to 50 percent of the Atlantic abyssal fauna (Nybakken 1988). Polychaete worms are also abundant, constituting 40 to 80 percent of the deep-sea fauna. Sea cucumbers are also common, making up for 30 to 80 percent of the biomass. Starfish (Asteroidea), sea lillies (Crinoidea), sponges (Hexactinellida) and sea urchins (Echinodea) are typically not abundant. Sea anemones (Anthozoa), sea pens (Pennatulacea) and horny corals (Gorgonacea) are the only common members of the phylum Cnidaria.

Underwater cold seep or hydrothermal vent environments have been identified in a wide range of underwater settings, and may support distinct benthic communities (Levin et al. 2000). Although not located directly within the Laurentian Subbasin study area, in 1986 a chemosynthetic benthic community was discovered in the Eastern Valley of the Laurentian Fan, at a depth of 3,850 m. The major epifaunal feature at the site of this methane/sulphide seep was vesicomyid clams (*Calyptogena*), with other clams (*Thyasira*, *Solemya*), gastropods, pogonophorans and galatheid crabs also observed (Petrecca and Grassle 1987). This 50 km² area is located approximately 60 km southeast of the study area (Figure 3.5). Although the potential for, and nature of, any such features and associated benthic communities in the Laurentian Subbasin is largely unknown, it is possible that the deeper, southern portions of the study area could potentially host similar cold seep or hydrothermal vent environments (DFO, unpublished information).

3.2.2.4 Invertebrates as Habitat

Invertebrate epifauna contribute to the overall complexity of the benthos by providing and altering habitat for other organisms. Sponges, bryozoans, hydroids, and corals form three-dimensional structures above the seabed which provide complex habitat for sessile and motile invertebrates, as well as for many fishes. Many algal and sessile invertebrate species attach to the shells of scallops and other molluscs (Breeze et al. 2002).

Other invertebrates affect benthic communities by altering sediment structure. For example, the sand dollar plows through fine sediments, either on top or just under fine and medium grain sands (Stanley and James 1971). This species is widespread throughout the Newfoundland and Nova Scotia offshore banks and modify surficial sediments, thereby affecting community structure of immobile invertebrates including tube-forming polychaetes (Steimle 1989).

3.2.2.5 Commercial Shellfish Species

The Laurentian Subbasin area contains several species of commercially important shellfish and several invertebrate species which have been identified as having commercial potential. The following section provides an overview of the life histories, habitat requirements and other characteristics of these species (Tables 3.8 and 3.9).

Commercial fishing for snow crab, Stimpson's surf clam, deep-sea scallop, Iceland scallop and shrimp occur to varying degrees within the study area. There are also efforts underway to develop directed fisheries for northern propellor clam and ocean quahog in the Scotian Shelf/Banquereau Bank region. These species are currently caught and processed as by-catch of Stimpson's surf clam harvesting on Banquereau Bank (C-NSOPB 2003). Detailed information on commercial fisheries in the Laurentian Subbasin is provided in Section 3.3.1 and Appendix C.

Table 3.8 Shellfish Species Which are Known or Likely to Occur Within the Study Area

Species	Habitat	Season	References
Snow Crab	St. Pierre Bank, Banquereau Bank and the slopes of the Laurentian Channel	Year-round	DFO 2002a, 2002b; Appendix C
Northern Shrimp	Laurentian Channel and St. Pierre Bank	Year-round	DFO 2002c; Appendix C
Deep-sea Scallop	St. Pierre Bank	Year-round	DFO 2001f; 2002d; Appendix C
Iceland Scallop	St. Pierre Bank	Year-round	DFO 2001b; Appendix C
Arctic Surf Clam (Stimpson's Surf Clam)	Sandy areas with depths up to 60 m; Banquereau Bank Likely on St. Pierre Bank	Year-round	DFO 1999; 2002e; Gosner 1978; C-NSOPB 2003
Stone Crab	Laurentian Channel	Year-round	DFO 1998; Tremblay <i>et al</i> 2001
Toad Crab	Likely on St. Pierre Bank	Year-round	DFO 1996a, 1996b; Hutchinson <i>et al.</i> 1981
Propeller Clam	Banquereau Bank Likely on St. Pierre Bank	Year-round	DFO (unpublished data); C-NSOPB 2003
Rock Crab	St. Pierre Bank (likely shallowest areas only)	Year-round	Tremblay and Reeves 2000; DFO 2000b
Sea Urchin	St. Pierre Bank (likely shallowest areas only)	Year-round	DFO 2000c; 2000d
Ocean Quahog	Banquereau Bank	Year-round	C-NSOPB 2003

Table 3.9 Shellfish Species Which are Known or Likely to Reproduce in the Study Area with Documented Locations and Times

Species	Location*	Approximate Time of Spawning	Duration of Planktonic Stage	References
Snow Crab	St. Pierre Bank Banquereau Bank	Mating in early spring, fertilized eggs carried for two years. Eggs hatch in late spring or early summer	Larvae spend 12-15 weeks in water column	DFO 2002b; C-NSOPB 2003
Northern Shrimp	3Ps; St. Pierre Bank and Laurentian Channel	Spawning occurs in late summer and fall	Eggs attached to female until following spring; hatch in inshore areas in spring and remain on the surface for a few months	Parsons 1993
Deep-sea Scallop	3Ps; St. Pierre Bank	August - October	30 - 60 days	DFO 2001f; 2002d
Iceland Scallop	3Ps; St. Pierre Bank	Late summer / early fall	Approximately five weeks from fertilization to settlement on the seabed	DFO 2001b; 2002j
Arctic Surf Clam (Stimpson's Surf Clam)	St. Pierre Bank Banquereau Bank	Fall (+ spring for inshore populations)	A few weeks	DFO 1999; 2002e; C-NSOPB 2003
Stone Crab	Laurentian Channel	Unknown	May be up to three months	DFO 1998; Tremblay et al. 2001
Toad Crab	Timing and location of reproduction not well understood			Tremblay et al. 2001
Propeller Clam	Timing and location of reproduction not well understood			DFO 1996c
Rock Crab	St. Pierre Bank (possibly)	Egg extrusion late October; eggs hatch the following spring or summer	5-8 weeks	Tremblay and Reeves 2000; DFO 2000b
Sea Urchin	St. Pierre Bank	Early spring	8-12 weeks	DFO 2000c; 2000d
* See Figures 3.9 and 3.10 for NAFO Divisions and Unit Areas.				

Snow Crab

Snow crab are decapod crustaceans occurring over a broad depth range (20 to 700 m) in the Northwest Atlantic, from Greenland south to the Gulf of Maine. Commercial sizes occur primarily on soft bottoms (mud or mud-sand) (DFO 2002a), particularly in water depths of 70 to 280 m (Elner 1985). Smaller crabs are also common on harder substrates (DFO 2002a).

Mating occurs during early spring, and females carry the fertilized eggs for approximately two years. The eggs hatch in late spring or early summer, and larvae spend 12 to 15 weeks floating in the water column before settling on the bottom (DFO 2002b). Snow crab feed on fish, clams, polychaete worms, brittle stars, shrimp, and crustaceans, including smaller snow crab. Their predators include various groundfish and seals (DFO 2002a).

Snow crab are fished extensively in the northeastern portion of the study area, as well as on the slopes of the Laurentian Channel and Banquereau (Section 3.3.1; Appendix C).

Northern Shrimp

In the Northwest Atlantic, northern (or pink) shrimp occur from the Davis Strait south to the Gulf of Maine, preferring areas where the bottom is soft and muddy in depths ranging 150 to 600 m and water temperatures of 2 to 6°C (DFO 2002c). Larger shrimp are generally found in deeper waters. Within the study area, northern shrimp are found both in the Laurentian Channel and on the St. Pierre Bank.

During the day shrimp rest and feed on the seabed and migrate at night into the water column to feed on zooplankton. Shrimp are an important prey for many species including Atlantic cod, Greenland and Atlantic halibut, skate, wolffish and harp seals. Northern shrimp are protandrous hermaphrodites. They mature from larvae as males, and mate as males for one to several years. They then change sex and spend the rest of their lives as mature females. In eastern Canadian waters, shrimp spawning occurs during the late summer and fall, and eggs remain attached to the female until the following spring. Berried females move into shallower inshore waters in late autumn and winter. Upon hatching in the inshore waters in spring, the larvae remain in the surface waters for a few months and then commence movement toward the bottom where they remain until maturation (Parsons 1993).

Shrimp are not fished extensively within the study area itself, but rather primarily to the west on the Scotian Shelf (Appendix C).

Deep-sea Scallop

The deep-sea scallop is a benthic, bivalve mollusc found only in the western North Atlantic, from the Strait of Belle Isle to Cape Hatteras. They prefer a sand/gravel bottom, and occur at depths of 35 to 120 m in aggregations which are referred to as "beds" (DFO 2001f). They are essentially immobile and do not migrate, although by contracting their muscle and "clapping" their shells together scallops are capable of limited forward movement (Harvey-Clark 1997). The major spawning period is from August to October (DFO 2002d). Because deep-sea scallops do not migrate, it can be assumed that they reproduce in the study area, but their offspring are carried by currents and may settle in other areas. Fertilized eggs develop in the water column and settle on the bottom within 30 to 60 days (DFO 2002d). In the study area, deep-sea scallops are harvested commercially on the St. Pierre Bank and on the slopes (Appendix C). The St. Pierre Bank is considered a major area of offshore fishing activity for deep-sea scallops (DFO 2001f).

Iceland Scallop

Iceland scallop are widely distributed throughout the sub-Arctic, and occur in commercial-sized aggregations on the St. Pierre Bank (DFO 2001b; Appendix C), with a typical depth range of 50 to 180 m. Iceland scallops prefer a hard bottom with variable substrate composition, consisting largely of sand, gravel, shell fragments, and stones (DFO 2001b). These bivalves are suspension feeders that filter water immediately above the sediment surface. Being filter feeders, they tend to be most abundant in areas with substantial water movements (Naidu 1997).

The spawning season is relatively short, and varies between geographic regions. Studies have suggested that Iceland scallop spawning may occur as early as April-May in some areas and as late as July-August in others (Wallace 1981; Crawford 1992). Scallops in this general area usually spawn in late summer, and juveniles settle on the seabed in the fall, with larvae development generally taking about five weeks from fertilization to settlement on the seabed (DFO 2002j). The time period for settlement to occur is not precisely defined and may occur from 30 to 60 days after fertilization, depending on water temperatures (Black et al. 1993).

Arctic Surf Clam

Arctic surf clam (also known as Stimpson's surf clam) are benthic, sedentary, bivalve molluscs. They are found along the western Atlantic Coast from Labrador to South Carolina (Gosner 1978), inhabiting sandy bottoms usually at depths of 60 m or less (DFO 2002e). Surf clams are found in large aggregations that are fished commercially year-round on the Banquereau Bank, to the immediate west of the study area (Appendix C). Therefore, their presence inside the study area (on St. Pierre Bank, and Banquereau Bank within their depth range) in non-commercial abundance is probable. Surf clams are filter feeders and have a very slow growth rate. Due to their slow growth rate and long lifespan, it is believed that natural

mortality is low (DFO 2002e). Arctic surf clams spawn during the fall, and there is some indication that inshore populations may also spawn in the spring (DFO 1999). Larvae are planktonic for a few weeks before settling in suitable habitat (DFO 2002e).

Stone Crab

Stone crab are found in the Northwest Atlantic at depths of 65 to 790 m, preferring temperatures above 0°C and sandy and clay seabeds. They are known to occur in the Laurentian Channel (DFO 1998; Tremblay et al. 2001). Although not a commercially exploited species at present, they are the target of an intermittent exploratory fishery. No migration is reported, so it is assumed that spawning occurs in the Laurentian Channel, but their offspring are carried by currents and may settle in other areas. It is not known what time of year mating and hatching occur. The planktonic stage of stone crab larvae may be up to three months in duration (Tremblay et al. 2001).

Toad Crab

Toad crab have been trapped at depths ranging from depths of 35 to 80 m, with concentrations generally in the 65 to 75 depth range (DFO 1996a; 1996b). Hutchenson et al. (1981) sampled toad crab just outside the study area (Figure 3.5), and it is likely that toad crab inhabit similar habitats on the St. Pierre Bank within the study area. Toad crabs are often found in the same habitat type as lobster and snow crab, where they are competitors for food (DFO 1996a). Food sources include small benthic invertebrates and decaying material (Harvey - Clark 1997). The timing of reproduction and migration events for toad crab is not well known (Tremblay et al. 2001).

Propeller Clam

The propeller clam is a large cylindrical bivalve mollusk found the Strait of Belle Isle south to Cape Cod on offshore banks in deep water, buried in sand with only its siphon exposed. It is a mobile suspension feeder, often found in association with sand dollars. Its predators include several commercial fish species, such as Atlantic cod, haddock, and yellowtail flounder (DFO 1996c).

The only North Atlantic Fisheries Organization (NAFO) subdivision containing a commercial propeller clam fishery within the study area is 4Vsc, on Banquereau Bank, to the immediate west of the Laurentian Subbasin area (Appendix C). Their presence in other parts of the study area (on St. Pierre Bank, within their depth range) in non-commercial abundance is possible. Little is known about the life history of this species, including spawning behaviour and timing (DFO 1996c).

Rock Crab

Rock crab are decapod crustaceans that are concentrated in shallow water to depths of 20 m from Labrador to Florida. They prefer sandy bottoms, but can be found on any substrate type (DFO 2000b; Tremblay and Reeves 2000). They are commercially fished inshore in NAFO Divisions 4Vn, 4Vs, and 3Ps (Appendix C); however, due to depth constraints, rock crab likely occur in the shallowest portions of the St. Pierre Bank only. Small rock crab are a common prey item for lobster. Commercial rock crab traps are usually set in traditional lobster fishing grounds but not during the lobster fishing season. Only large (greater than 102 mm carapace width), male rock crab are retained in the fishery (Tremblay and Reeves 2000).

Egg extrusion appears to occur in late October. The eggs hatch the following spring or summer into larvae that are planktonic for 5 to 8 weeks, depending on the temperature (DFO 2000b). Because rock crab do not migrate it is likely that they spawn within the study area. However, they may settle in different areas after an extended planktonic stage.

Sea Urchin

Green sea urchins are echinoderms with a circumpolar range in the North Pacific and North Atlantic Oceans. They can be found intertidally to depths of 200 m, but are particularly abundant at depths of 0 to 10 m, generally along hard or rocky substrates (DFO 2000c). Urchins are fished commercially in NAFO Subdivisions 4Vsb and 4Vn (Appendix C). The urchin fishery is inshore and harvesting is by diver only. Although urchins are found within the study area (Nesis 1965), they are not harvested commercially. Spawning occurs in early spring, coinciding with the spring phytoplankton bloom. After the fertilized eggs hatch, the larvae are planktonic for 8 to 12 weeks before settling permanently to the bottom. Sea urchins consume mostly seaweed, but attached bottom animals and decaying organic matter are also eaten. A variety of fish, crabs and seabirds are predators (DFO 2000d).

3.2.3 Fish

The study area can be divided into four primary fish habitat types, based on the physiography of the area (Section 3.1.1). The St. Pierre Bank is relatively shallow and cold, with a bottom temperature generally between 0 and 2°C (Colbourne et al. 2002). The predominant substrate type on the St. Pierre Bank is fine to coarse sand, except on the west-central part of the bank, which is rocky. The second fish habitat type occurs along the slopes of the bank. The Laurentian Channel slopes to the west, and Halibut Channel slopes to the east of St. Pierre Bank (see Figure 3.1). The substrate on the slope is primarily coarse sand. The third fish habitat is the area of the slope and the Laurentian Channel, with water depths of greater than 200 m, and substrate predominately of silt and clay. On average, the water is also consistently warmer than on the shallower bank areas (Section 3.1.7). The fourth fish habitat area is the Banquereau Bank. The predominant substrate type on Banquereau Bank is sand and gravel, with a clockwise water

circulation around the outer edges of the bank (Amos and Nadeau 1988, as cited in C-NSOPB 2003). The southwest corner of the bank has a high level of tidal mixing and is very productive (Rutherford and Breeze 2002, as cited in C-NSOPB 2003). Finally, the large area of the abyssal south of the Laurentian Channel supports a variety of fish species not found on the shallow banks.

Fish assemblages along the continental slope, from 400 to 1,200 m, are defined by depth zones of 400 to 800 m, and 800 to 1,200 m (Markle et al. 1988, as cited in Breeze et al. 2002). Beyond a depth of 1,200 m in the abyssal, sampling has been very patchy and it is difficult to characterize species and assemblages in this region (Merrett and Haedrich 1997, as cited in Breeze et al. 2002). Redfishes, longfin hake, marlin-spike, and witch flounder dominate assemblages from 400 to 800 m depths. Black dogfish, longnose eel, marlin-spike, and rock grenadier dominate assemblages from 800 to 1,200 m depths. A study conducted by Pohle et al. (1992, as cited in Breeze et al. 2002) also identified Atlantic saury, blue hake, and black dogfish as deepwater species (>300 m) with potential as commercial fisheries.

Other fishes that occur in smaller numbers in the very deep waters of the continental shelf area include: longhorn sculpin, sea raven, American straptail grenadier, deep-sea cat shark, backfin tapirfish, shortspine tapirfish, eelpout, Gray's cutthroat eel, snubnose slime eel, spiny eel, knifenose chimera, lanternfish, trunkfish, and several species of skate (freckled, little, and Jensen's) (Pohle et al. 1992, as cited in Breeze et al. 2002).

Fish assemblages on the continental shelf and slope are relatively distinct and linked to water depth (Gomes et al. 1992), with areas of the slope between 90 and 200 m having different species than areas below 200 m. However, as Gomes et al. (1992) point out, many fish species occur over a depth range of several hundred metres along the slope of the St. Pierre Bank. Some species move seasonally between shallow and deep water, while others move continuously between water depths.

3.2.3.1 Species Known or Likely to Occur in the Laurentian Subbasin

A summary of fish species which occur within the study area and the season in which each is most likely to occur is provided in Table 3.10. The species which are known or likely to spawn within the area, along with documented spawning locations and times are listed in Table 3.11. This table also identifies the duration of the planktonic life stage(s) of each species, and consequently the time at which they may be particularly vulnerable to disturbance.

The following section provides an overview of these fish species, including information on their distribution and abundance, habitat requirements and other characteristics (species are discussed in alphabetical order). A number of species at risk are known to occur within the study area. Information on these species is also provided below, and summarized in Section 3.2.3.2.

Table 3.10 Fish Species Which are Known or Likely to Occur Within the Study Area

Species	Habitat	Season of Occurrence	References
Alewife / Blueback Herring (Gaspereau)	St. Pierre Bank	Fall and Winter Spawning migrations to fresh water in late spring, which are completed by mid-summer	DFO 2001c; Scott and Scott 1988
American Plaice	Slope of the Laurentian Channel and Banquereau Bank	Year-round	Scott and Scott 1988
American Striptail Grenadier	Abyss	Only one record off the eastern tip of Banquereau Bank in 1896	Goode and Bean 1896, in Scott and Scott 1988
Atlantic Argentine	Lower Slope of St. Pierre Bank and Laurentian Channel	Year-round	Scott and Scott 1988
Atlantic Cod	Throughout study area: St. Pierre Bank, Laurentian Channel, Halibut Channel, Banquereau Bank	Year-round	DFO 2002f; Scott and Scott 1988
Atlantic Halibut	Slope of St. Pierre Bank and in the Laurentian Channel, Move seasonally between deep and shallow waters	Year-round	Scott and Scott 1988
Atlantic Herring	Laurentian Channel, St. Pierre Bank and Banquereau Bank	Winter Migrate across Cabot Strait in summer	Scott and Scott 1988
Atlantic Salmon	Laurentian Channel and St. Pierre Bank	Spring until late fall Migrations to and from northern areas (Labrador and Greenland)	Ritter, 1989; Scott and Scott, 1988
Atlantic Saury	Continental shelf and abyss	Summer - Fall	Scott and Scott 1988
Black Dogfish	Laurentian Channel, Near or on bottom and Continental slope and abyss	Year-round	Scott and Scott 1988
Bluefin Tuna	St. Pierre Bank and slope	Summer	Scott and Scott 1988
Blue Shark	St. Pierre Bank and Laurentian Channel	Summer; Some sightings year-round, except December and January	Scott and Scott 1988
Capelin	St. Pierre Bank and Green Bank	July-April	Scott and Scott 1988
Cusk	Slopes of Laurentian Channel	Year-round	Harris et al, 2002; Scott and Scott, 1988
Deep-sea Cat Shark	Abyss	Unknown	Scott and Scott 1988
Eel, Slatjaw (Gray's) Cutthroat	Abyss	Year-round, spawning likely in summer months	Scott and Scott 1988
Eel, Long-nosed	Continental slope and abyss	Year-round	Scott and Scott 1988
Eel, Spiny	Abyss	Year-round	Scott and Scott 1988
Eel, Subnose (Slime)	Abyss	Year-round	Scott and Scott 1988
Eelpout	Abyss	Year-round	Scott and Scott 1988
Greenland Halibut	Deeper parts of slope of the St. Pierre Bank and the Laurentian Channel	Year-round	Scott and Scott 1988
Haddock	Low numbers throughout the shelf and in deep water along the St. Pierre Bank slope and Laurentian Channel. Shallow shelf waters in summer	Spring - Fall Migrate to Cape Hatteras during winter	DFO 2001d; Scott and Scott 1988
Hagfish	St. Pierre Bank and Laurentian Channel	Year-round	Scott and Scott 1988
Hake, Blue	Abyss	Year-round	Scott and Scott 1988

Species	Habitat	Season of Occurrence	References
Hake, White	Southern edge of St. Pierre Bank and eastern edge of Laurentian Channel	Year-round	Scott and Scott 1988
Hake, Longfin	Laurentian Channel, deeper waters on slope, Continental slope	Year-round	Scott and Scott 1988
Hake, Silver	Laurentian Channel, deeper waters on slope	Year-round	Scott and Scott 1988
Knifefish Chimera	Abyss	Unknown	Scott and Scott 1988
Lanternfish	Abyss	Unknown	Scott and Scott 1988
Longhorn Sculpin	Abyss	Year-round	Scott and Scott 1988
Lumpfish	St. Pierre Bank	Winter	Scott and Scott 1988
		Migrate inshore to spawn during late spring-summer	
Mackerel	Slope between the St. Pierre Bank and the Laurentian Channel	Winter	Scott and Scott 1988
		Migrate northeast to spawn in summer	
Marlin-Spike	Lower Slope of St. Pierre Bank and Laurentian Channel, Continental slope, Muddy bottoms (benthic fish)	Year-round	Scott and Scott 1988
Rock Grenadier	Continental slope and abyss	Year-round	Scott and Scott 1988
Monkfish	Southwest slope of St. Pierre Bank and Laurentian Channel	Year-round	DFO 2000e; Scott and Scott 1988
Northern Sand Lance	St. Pierre Bank, Shallow shelf areas	Year-round	Scott and Scott 1988
Pollock	Slope between the St. Pierre Bank and the Laurentian Channel	Winter	Scott and Scott 1988
Porbeagle	St. Pierre Bank and Laurentian Channel	Migrate inshore during summer	
Redfish	St. Pierre Bank, Banquereau Bank and Laurentian Channel	Spring and Summer	Scott and Scott 1988
	Variable depth distribution throughout the year	Year-round	DFO 2000f
Sea Raven	Abyss	Year-round	Scott and Scott 1988
Skate, Barndoor	Slope and Laurentian Channel, Not common in study area	Year-round	Scott and Scott 1988
Skate, Smooth	Slopes between St. Pierre Bank, Banquereau Bank and Laurentian Channel, over soft mud and clay bottoms	Some inshore populations migrate offshore seasonally	
Skate, Spinytail	Slope between St. Pierre Bank and Laurentian Channel	Year-round	McKone and LeGrow 1983; Scott and Scott 1988
Skate, Thorny	St. Pierre Bank and Banquereau Bank	Year-round	Scott and Scott 1988
Skate, Winter	Banquereau Bank	Year-round	McKone and LeGrow 1983; Scott and Scott 1988
Skate, Little	Abyss	Year-round	Scott and Scott 1988
Skate, Shorttail (Jensen's)	Abyss	Move inshore in winter and offshore in summer	Scott and Scott 1988
Spiny Dogfish	St. Pierre Bank	Unknown	Scott and Scott 1988
Squid	Slopes of Laurentian Channel and St. Pierre Bank	June	Walsh 1993
Swordfish	St. Pierre Bank and Laurentian Channel	Spring, Summer, Fall	Breeze et al 2002
Tapirfish, Backfin	Abyss	June to November	Scott and Scott 1988
Tapirfish, Shortspine	Abyss	Unknown	Scott and Scott 1988

Species	Habitat	Season of Occurrence	References
Trunkfish	Abyss	Only one reported capture off Nova Scotia banks in 1953	Leim and Scott 1966, in Scott and Scott 1988
Witch Flounder	Laurentian Channel, Southern St. Pierre Bank and continental slope	Year-round	Bowering 1982
Wolffish, Northern	Laurentian Channel and Southern St. Pierre Bank (Rare)	Year-round	DFO 2002i; Scott and Scott 1988
Wolffish, Spotted	Laurentian Channel (Rare)	Year-round	DFO 2002i; Scott and Scott 1988
Wolffish, Atlantic	Slope and Laurentian Channel	Year-round	DFO 2002i; Scott and Scott 1988
Yellowtail Flounder	St. Pierre Bank and Banquereau Bank	Spring and Summer; Migrate to the Laurentian Channel in winter	Scott and Scott 1988

Table 3.11 Fish Species Which are Known or Likely to Reproduce in the Study Area with Documented Locations and Times

Species	Spawning Location*	Approximate Spawning Time	Duration of Planktonic Stage	References
American Plaice	Throughout shelf area, St. Pierre Bank	May-June	12 to 16 weeks until metamorphosis	Walsh 1994; Morgan 2001
Atlantic Cod	St. Pierre Bank, Banquereau Bank and Halibut Channel (3Psf, 3Psg, 3Psh, 4Vsc)	March to June	10 to 12 weeks at 1-3°C	DFO 2002f; Hutchings <i>et al.</i> 1993; C-NSOPB 2003
Atlantic Halibut	Spawning grounds not clearly defined but likely at slope of St. Pierre Bank	February to April	3-4 months until metamorphosis	Zwanenburg <i>et al.</i> 1997
Atlantic Herring	Banquereau Bank	August to November	Fertilized eggs remain on bottom until hatching	C-NSOPB 2003
Cusk	Southwestern slope of Laurentian Channel	May to August, peaking in June	Remain planktonic until 50 mm in length; growth rate of juvenile cusk not documented	Harris <i>et al.</i> 2002; Scott and Scott 1988
Greenland Halibut	Laurentian Channel	Winter	Unknown	Scott and Scott 1988
Haddock	St. Pierre Bank	June to July	4 to 5 weeks until hatching	Templeman and Bishop 1979; Page and Frank 1989; Scott and Scott 1988
Hake, White	Southwestern slope of St. Pierre Bank	June to August	Unknown	Kulka 1996a
Mackerel	South Laurentian Channel	June to July	1 week at 11-14°C (Note this is a pelagic species)	Scott and Scott 1988
Pollock	NAFO Unit Areas 3Psg, 3Psh	Late Summer - Fall	Hatching within 1-2 weeks @ 6°C	Murphy 1996
Porbeagle Shark	St. Pierre Bank and Laurentian Channel (3Ps)	Winter	Ovoviviparous (live young released).	Campana <i>et al.</i> 2001
Redfish	Along Shelf (3Ps and 4Vn) and in the deeper waters of the channel	Mating in late winter; Young released in April to July	Ovoviviparous (live young released).	Ni and Sandeman 1997
Skate	NAFO Unit Area 3Ps	Year-round	Deposit egg cases which contain one embryo each	Kulka 1996b
Witch Flounder	Along the slope of St. Pierre Bank (3Psg, 3Psh) at depths greater than 500 m	January to May	1-2 weeks until hatching at 8°C	Bowering 1996; Scott and Scott 1988
Wolfish	It is not known with certainty if wolfish spawn within the study area. If so, it would likely along the slope of the St. Pierre Bank	September to November	Larvae remain benthic until 18 mm in length. Become planktonic when yolk sac is absorbed.	Scott and Scott 1988; Simpson and Kulka 2002

* See Figures 3.9 and 3.10 for NAFO Divisions and Unit Areas.

Where applicable, and to help define locations, reference is made to NAFO Divisions and Unit Areas (see Figures 3.9 and 3.10). These administrative regions are discussed in detail in Section 3.3.1.

Alewife

Alewife and blueback herring are anadromous fish, which together are known as gaspereau (DFO 2001c). The alewife spends most of its adult life in the ocean, entering fresh water to spawn. In the ocean, the alewife has been identified from southern Newfoundland south to North Carolina. Its preferred depth range is 56 to 110 m, with most occurring at depths less than 100 m. In the study area it is found on the St. Pierre Bank (Scott and Scott 1988). Spawning migrations to fresh water begin in late spring and are completed by mid-summer. They return to the ocean after spawning is complete (DFO 2001c).

At sea, the adult alewife's diet consists mainly of zooplankton, including amphipods, copepods, mysids, small fishes and fish eggs. Little is known about predators of alewife, although they have been found in the stomachs of predaceous fishes, including Atlantic salmon and striped bass, which do not occur in the study area (Scott and Scott 1988).

American Plaice

Occurring along the slope of the Laurentian Channel, American Plaice likely occur throughout the study area in depths between 90-200 m (Gomes et al. 1992). They appear to be more abundant at intermediate depths along the slopes of the St. Pierre Bank (Morgan et al. 2002). Spatial analysis of DFO research vessel catch data indicated a drop in density during both spring and fall surveys during the late 1980s and early 1990s, with a measurable decrease after 1991 (Kulka et al. 2003). Spawning occurs in the St. Pierre Bank area during May and June, with peak spawning in May (Morgan 2001). Fertilized eggs float near the surface. The incubation time depends on the water temperature, and is approximately one to two weeks at 5°C (Scott and Scott 1988).

The food consumed by American plaice depends on the size of the fish. Larval plaice consume microscopic plants and invertebrates in the surface waters. As they grow and settle to the bottom, they consume larger benthic invertebrates such as sand dollars, brittle stars, sea urchins, shrimp, and polychaete worms (Scott and Scott 1988). As adults, plaice also consume capelin and sand lance (Pitt 1989). Off Newfoundland, fish are a larger part of their diet (Breeze et al. 2002).

Atlantic Argentine

The Atlantic argentine is a deepwater fish, reported from depths of 183 to 256 m. In the study area, argentine occur over the lower slope of the St. Pierre Bank. There is no information on seasonal migrations, and very little on spawning in the North Atlantic. It is believed that spawning occurs during

March and April on the Scotian Shelf. Atlantic argentine feed primarily on krill, euphausiids, and arrow worms. Reported predators of Atlantic argentine include redfish and hake (Scott and Scott 1988).

Atlantic Cod

Atlantic cod occur throughout the study area, and are likely a mix of populations or seasonal migrants from other areas (DFO 2002f). Fish from the northern Gulf regions (3Pn4RS) mix with fish from 3Ps, St. Pierre Bank (during winter, for example). In the spring and summer, cod from the offshore areas of 3Ps likely migrate inshore to Placentia Bay and some even to the northeast coast, returning in the fall (DFO 2002f). Cod from Placentia Bay do not appear to migrate to the Gulf area (Lawson et al. 1998). A substantial portion of the southern Gulf stock remain in 4Vn until May, but are found in 4Tfg in November (Sinclair and Currie 1994). Cod from the southern Gulf of St. Lawrence migrate to the Laurentian Channel to spend the winter (Breeze et al. 2002). Over 100,000 metric tonnes of cod from four populations were estimated along the flanks of the channel in January during the mid-1990s (Campana et al. 1999).

Preferring cool temperatures, cod usually spend much of their time feeding near the bottom in deep water. Cod larvae feed on a variety of small crustaceans, including copepods, amphipods, and barnacle larvae. Juvenile and young adult cod eat crustaceans such as small lobsters, mysids, shrimps, toad and hermit crabs. As cod reach maturity (at approximately 50 cm), fish become prominent in their diet. Cod are opportunistic feeders, and depending on availability, capelin, sand lance, redfish, and herring are the preferred prey. Adult cod are eaten by seals and toothed whales, while adult cod, squid, and pollock prey on juvenile cod (Scott and Scott 1988).

The primary spawning ground in the Laurentian Subbasin is on the St. Pierre Bank, in NAFO areas 3Psf, 3Psg, and 3Psh (rather than on the slope of the St. Pierre Bank) (Hutchings et al. 1993). Spawning is from March to June (Hutchings et al. 1993; Ouellet et al. 1997), with the eggs, larvae and early juvenile stages in the plankton for 10 to 12 weeks. Young juveniles move to coastal areas at night, spending the daytime in deeper waters (20 m). Older juveniles (aged three to four years) overwinter along the edge of the Laurentian Channel (Breeze et al. 2002).

Spatial analysis of DFO research vessel catch data indicated a dramatic drop in both the distribution and density of cod during both spring and fall surveys, starting in the late 1980s and continuing until the late 1990s (Kulka et al. 2003). In May 2003, the Laurentian North population of Atlantic cod, which extends from the northern Gulf of St. Lawrence to Newfoundland's south coast, was assessed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Maritimes population of Atlantic cod remains in the special concern category (see Section 3.2.3.2 for additional information and specific stocks) (COSEWIC 2003a).

Atlantic Halibut

The largest of the flatfishes, Atlantic halibut are found along the slope of the St. Pierre Bank and in the Laurentian Channel. Spatial analysis of DFO research vessel catch data indicated a decrease in abundance from the mid-1980s to the late 1990s, with a slight increase noted from 1998 to 2000 (Kulka et al. 2003). Atlantic halibut move seasonally between deep and shallow waters, avoiding temperatures below 2.5°C (Scott and Scott 1988). The spawning grounds of the Atlantic halibut are not clearly defined, but are likely located in the study area, on the slope between the St. Pierre Bank and Laurentian Channel. Spawning occurs between February and April in deep water (1,000 m or more). Fertilized eggs are slightly positively buoyant, meaning that they are naturally dispersed and only gradually float toward the surface. Once hatched, the developing larvae live off their yolk for the next six to eight weeks while their digestive system develops so they can begin feeding on natural zooplankton. After a few weeks of feeding, they metamorphose from a bilaterally symmetrical larva to an asymmetrical flatfish, and are ready to assume a bottom-living habit. At this point they are approximately 20 mm long.

As juveniles, Atlantic halibut feed mainly on invertebrates, including annelid worms, crabs, shrimps, and euphausiids. Young adults (between 30 to 80 cm in length) consume both invertebrates and fish, while mature adults (greater than 80 cm) feed entirely on fishes. There are no confirmed predators of Atlantic halibut (Scott and Scott 1988).

Atlantic Herring

Atlantic herring are pelagic, schooling fish which are found to depths of 200 m. In the study area, herring occur on the St. Pierre Bank and on the slope of the bank during winter. During summer, schools of herring migrate across Cabot Strait to feeding grounds in the southern Gulf of St. Lawrence (Scott and Scott 1988). Spawning does not occur within the study area, but rather on the Scotian Shelf in NAFO regions 4Wh and 4Wi (Stephenson 1997). Herring eggs are demersal, adhering to gravel or seaweeds. Hatching occurs within one to two weeks, the larvae are planktonic (Scott and Scott 1988; Breeze et al. 2002).

The primary food of herring at all life stages is plankton, which is consumed mainly during the daylight hours. Young herring consume microscopic phytoplankton, eating larger invertebrate zooplankton as they grow. Adult herring consume large amounts of copepods, euphausiids and fish eggs, filtering the small invertebrates out of the water using their gill rakers. Herring are an important food source for many other fishes, birds and marine mammals. They are eaten by squid, dogfish, porbeagle, skate, salmon, Atlantic cod, silver and white hake, mackerel and flounder (Scott and Scott 1988).

Atlantic Salmon

Atlantic salmon are anadromous fish, living in freshwater rivers for the first two years of life before migrating to sea. Salmon migrate from northeastern North America in the spring and summer to waters off Labrador and Greenland to feed for one or more years. They return to coastal North America, crossing the Laurentian Channel in the fall (Ritter 1989).

Juvenile Atlantic salmon mainly eat the larvae of aquatic insects including caddisflies and blackflies. As adults in the ocean, salmon consume euphausiids, amphipods, and fishes such as herring, capelin, small mackerel, sand lance, and small cod. Upon re-entering freshwater to spawn, Atlantic salmon do not eat. In the ocean, adult salmon are preyed upon by seals, sharks, pollock and tuna (Scott and Scott 1988).

Atlantic salmon were officially listed as endangered in the Bay of Fundy in May 2001 (COSEWIC 2003a), and conservation efforts to prevent this from occurring in Newfoundland have been implemented.

Atlantic Saury

Atlantic saury is a small pelagic fish, often mistaken for young swordfish. They are found schooling in the warm surface waters of the open ocean, preferring temperatures of 8 to 24°C. Within the study area they are found in small numbers on the St. Pierre Bank and in schools in the abyssal area. They undergo two migrations: seasonal and diurnal. They migrate to deeper water (50 m) during daylight hours, and migrate south during winter months. Spawning occurs during the winter and early spring outside of the study area (Scott and Scott 1988). This species is not fished commercially in Canadian waters. The diet of Atlantic saury consists of zooplankton, mainly copepods and euphausiids. Predators include Atlantic cod, pollock, mackerel, tunas, and dolphins (Scott and Scott 1988).

Black Dogfish

Black dogfish are small deepwater sharks that live near or on the bottom at depths to 1,700 m or more. They are concentrated in the Laurentian Channel during spring (Simpson and Kulka 2001), but are found within the study area year-round. Black dogfish are ovoviviparous, bearing live young. Their diet consists mainly of cephalopods, pelagic crustaceans, jellyfish, and redfish. They have no known predators (Scott and Scott 1988).

Bluefin Tuna

Bluefin tuna is a large, migratory pelagic species found in the study area on the St. Pierre Bank and slope during the summer months (Breeze et al. 2002; Scott and Scott 1988). They migrate into Canadian waters from Florida and the Gulf of Mexico, and in the fall they migrate again, some back to the Gulf of

Mexico and others to Europe. Spawning does not occur in Canadian waters. Tuna are voracious, active predators. In Canadian waters they prey on both pelagic and groundfish, including capelin, herring, mackerel, silver hake and white hake. Adult bluefin tuna have few natural predators, although a few fall prey to killer whales and mako sharks (Scott and Scott 1988).

Bigeye and yellowfin tuna occupy a similar range as the bluefin tuna (Scott and Scott 1988). However, the northern extent of their range is the Scotian Shelf, and they are not caught within the bounds of the study area (Appendix C).

Blue Hake

The blue hake is a benthopelagic species living on mud bottoms at depths of 1,300 to 2,500 m, rarely moving up into the water column. It prefers a water temperature of approximately 2 to 3°C. Within the study area it is found year round offshore in the abyssal area. It is not known if they spawn within the study area. Their diet consists mainly of benthic invertebrates, including crustaceans and squid. There are no records of predation, but it is suggested that the blue hake is preyed on by large benthic fishes (Scott and Scott 1988). This species is not fished commercially in Canadian waters.

Blue Shark

The blue shark is a large, pelagic species found worldwide. They are found in Canadian waters, including the southern Newfoundland banks, primarily during summer. However, there have been several sightings in every month except December and January. In the North Atlantic, tagging studies have shown that blue sharks move clockwise. The exact locations of reproduction/pupping are unknown but do not occur over the continental shelves (Scott and Scott 1988). Blue sharks consume mainly pelagic fishes and squid.

Capelin

Capelin are a small, pelagic schooling species. In the Northwest Atlantic, they occur along the coasts of Labrador and Newfoundland, on the Grand Banks and in the Estuary and Gulf of St. Lawrence (DFO 2001g). At maturity, schools of adult capelin migrate inshore to spawn on beaches during June and July. After the eggs have hatched, the larvae exit the beach gravel and most are rapidly carried out of the bays by surface currents (DFO 2000g). Capelin are a key element of the food chain, and are consumed by numerous predators, including cod, salmon, Greenland halibut, seabirds, whales and seals (DFO 2000g).

Cusk

Cusk are solitary, slow-swimming groundfish found on both sides of the North Atlantic, preferring rocky bottoms. In Canadian waters, this species is common in the Gulf of Maine, Gulf of St. Lawrence

and the southwestern Scotian Shelf (Harris *et al.* 2002; Scott and Scott 1988). With a preferred depth range of 128 to 144 m, some have been caught as deep as 600 m. In the study area, cusk are found along the slopes of the Laurentian Channel (Harris *et al.* 2002). Spawning occurs from May to August, peaking in June. In the study area, cusk spawn along the western slope of the Laurentian Channel (Harris *et al.* 2002).

The diet of cusk is not well documented because their stomachs usually evert when they are brought to the surface. Studies have shown that in European waters, cusk feed on crab, molluscs, krill, cod, and halibut. Their diet is presumed to be the same in Canadian waters. There have been observations of predation of cusk by hooded seals in Greenland (Scott and Scott 1988), but there is no record of cusk predation on the Scotian Shelf (Harris *et al.* 2002).

In May 2003 cusk were designated as a threatened species by COSEWIC (2003a).

Greenland Halibut

Greenland halibut (also known as turbot) occupy deeper parts of the slope of the St. Pierre Bank and the Laurentian Channel (Gomes *et al.* 1992). Unlike most flatfishes, Greenland halibut spend much of their time swimming off the bottom, behaving like a pelagic species. With a depth range of 90 to 1,600 m, Greenland halibut are usually found at depths around 450 m (Scott and Scott 1988). Spatial analysis of DFO research vessel catch data indicated a decrease in abundance from the late 1980s to early 1990s during both survey seasons (spring and fall) (Kulka *et al.* 2003). Spawning is thought to occur in the area of the southern Esquiman Channel and the Laurentian Channel during winter (Templeman 1973).

Greenland halibut are bathypelagic predators and feed on a variety of fish and invertebrates, including capelin, Atlantic cod, redfish, sand lance, crustaceans (especially shrimp), squid and young Greenland halibut. Hooded seals, adult Atlantic cod and adult salmon prey upon juvenile Greenland halibut.

Haddock

Being close to the northern limit of their range, haddock likely occur in low numbers throughout the shelf and in deep water along the slope of St. Pierre Bank in the Laurentian Channel (Murphy 1995; Gomes *et al.* 1992; Breeze *et al.* 2002). During the summer, haddock occupy shallow, open, shelf waters, but move to depths of 360 m during the winter (Breeze *et al.* 2002).

The St. Pierre Bank (NAFO Division 3Ps) is a known spawning area for haddock (Page and Frank 1989; Begg 1998). Peak spawning for haddock occurs in June and July in Newfoundland waters (Templeman *et al.* 1978; Templeman and Bishop 1979). The haddock is an example of a species that communicates by sound during reproductive rituals, in which the male fish emits a series of knocking, rasping and humming sounds during courtship (Hawkins 1986).

In the mid-1950s, a substantial haddock fishery took place on the St. Pierre Bank. However, there is not currently a directed fishery for haddock in 3Ps. Recent surveys have found very few haddock, and although recent surveys have suggested some increases in stock size, the biomass is at a low level compared to the mid to late 1980s (DFO 2001d). Spatial analysis of DFO research vessel catch data indicated a decrease in abundance in both spring and fall surveys starting in the late 1980s until the late 1990s; recovery was noted during 1998 to 2000 for both seasons (Kulka et al. 2003).

Haddock are primarily bottom feeders, with food varying with size (DFO 2001d). They prey primarily on crustaceans for the first few years, with capelin, sand lance and herring becoming more abundant in adult diets. On fishing grounds, such as the St. Pierre Bank, haddock prey most commonly on capelin, hake, American eels, herring, and large quantities of capelin and herring eggs. In turn, cod, pollock and hake prey upon juvenile haddock. Adult haddock are eaten by harbour and grey seals (Scott and Scott 1988).

Hagfish

The Atlantic hagfish is likely found on the St. Pierre Bank and Laurentian Channel. Commonly occurring at depths of 30 m, they have been found as deep as 958 m. Requiring a high salinity (30 ppt or more) and low temperature (greater than 12°C), they are usually found in deeper waters with muddy substrates. Hagfish remain covered with mud for extended periods, suggesting that they are facultatively anaerobic (Scott and Scott 1988). Hagfish are voracious scavengers, attacking, burrowing into, and consuming the internal organs of fishes caught on longlines and bottom gill nets. They also consume polychaetes and crustaceans. Although they have few predators as adults (due to the viscous slime the hagfish produces on its skin), young hagfish have been found in the stomachs of Atlantic cod and halibut (Scott and Scott 1988). Hagfish do not spawn in the study area.

White, Silver and Longfin Hake

White hake is a benthic species, preferring the warmer (5 to 11°C) slope waters at depths greater than 200 m, but seasonally occurring over a wide range of depths (Kulka and Simpson 2002). In the study area, white hake are most abundant on the southern edge of the St. Pierre Bank and on the eastern edge of the Laurentian Channel. Silver and longfin hake also occur in lower densities in deeper waters on the slope (Gomes *et al.* 1992). Hake do move above the 150 to 200 m depth range, with occasional appearances as shallow as 100 m (Gomes *et al.* 1992). During the spring, longfin hake migrate to the deeper waters of the Laurentian and Hermitage Channels (Simpson and Kulka 2002). Only white hake spawn within the study area, on the southwestern slope of the St. Pierre Bank between June and August (Kulka 1996a), producing planktonic eggs and larvae that drift in the upper 50 m of the water column (Markle *et al.* 1982). Silver hake spawn over Emerald and Western Banks, producing buoyant eggs which hatch in a few days. Larvae aggregate in surface waters (less than 20 m) during the day (Fortier and Villeneuve 1996).

White and silver hake prey heavily on other fishes. In Newfoundland waters, white hake prey upon silver, red, and longfin hake, Atlantic cod, herring and flatfish (Kulka and Simpson 2002). Silver hake consume mostly gadids, including their own young. They also prey upon some pelagic species, including Atlantic herring, smelt, sand lance, mackerel and squid. Predators of hake, especially of juveniles, include seals and Atlantic cod (Scott and Scott 1988).

Longnose Eel

The longnose eel is a bottom dwelling fish, found at depths ranging from 238 to 3,656 m, preferring water 1.4°C or warmer. They are found within the study area, in the deep abyssal south of the Grand Banks and Banquereau Bank. They spawn in the summer. No migration is described for the longnose eel, therefore it is assumed that spawning occurs within the study area. The diet of longnose eels consists of cephalopods, juvenile finfish, amphipods and other benthic crustaceans (FishBase 2002). This species is not fished commercially in Canadian waters.

Lumpfish

Lumpfish are common on the St. Pierre Bank and on Green Bank (Gomes et al. 1992) to depths of 330 m. A spawning migration to shallow, inshore water occurs during the late spring-early summer (Scott and Scott 1988). The preferred spawning grounds of this species are the shallow, rocky shores, with abundant seaweed along the coasts of Newfoundland and Nova Scotia, outside of the study area.

Their food consists mainly of invertebrates such as krill, amphipods, copepods and jellyfish, supplemented by fish like herring and sand lance (DFO 2002g). Adult lumpfish tend to feed mainly during the winter. Lumpfish are prey for seals and other marine mammals (Scott and Scott 1988).

Mackerel

Atlantic mackerel are pelagic and are among the most active of migratory fishes, forming large schools containing fish of uniform size. They are found at depths of 70 to 200 m, along the slope of the St. Pierre Bank during the winter, at temperatures of 9 to 12°C (Scott and Scott 1988). Spawning occurs in the surface waters of the southern Laurentian Channel in June and July (Gregoire 1997). Hatching occurs within one week at temperatures of 11 to 14°C (Scott and Scott 1988). Larvae aggregate high in the water column at night, but move deeper during the day. During the morning and afternoon periods, larvae concentrate in the thermocline, at a depth of 10 to 20 m (Fortier and Villeneuve 1996). Larval mortality is high (50 percent) due to predation by pelagic fish and groundfishes and larger larvae (Ahens 1985).

Mackerel feed in different ways at different stages of their development. Early on, they filter large amounts of small planktonic organisms using their gill rakers. As adults, mackerel are selective feeders, consuming planktonic invertebrates such as amphipods, euphausiids, shrimps, crab larvae and fish eggs. They also prey on young fishes, including capelin and herring (Scott and Scott 1988).

Marlin-Spike (Common Grenadier)

The marlin-spike is a benthic fish, living on muddy bottoms. Off Newfoundland, it is most abundant at depths of 183 to 732 m. In the study area, it occurs on the lower slope of the St. Pierre Bank locations. It is believed that spawning occurs during the summer, although the location of spawning and the characteristics of eggs and larvae are not known (Scott and Scott 1988).

Monkfish/Goose Fish

Monkfish (sometimes also called angler fish) occur along the southwest slope of the St. Pierre Bank and in the Laurentian Channel (Simpson and Kulka 2001) to a depth of 650 m, with a seasonal migration to shallower shelf waters during the summer. Spawning is not known to occur in the study area. Inshore summer spawning produces floating egg masses up to 12 m long (DFO 2000e). Larvae spend several months in the surface waters before settling to the bottom (Scott and Scott 1988).

Adult monkfish are voracious predators, consuming most invertebrates and fishes that that can be attracted by the "lure" on the top of the head. There have even been seabirds found in their stomachs (Scott and Scott 1988).

Northern Sand Lance

The northern sand lance is a small benthic fish found in shallow shelf areas at depths less than 90 m (Scott and Scott 1988). Northern sand lance occurs on the St. Pierre Bank, but do not spawn within the study area. During the winter, northern sand lance migrate to shallow water to spawn. The eggs fall to the bottom, where they stick to sand grains. After hatching, the larvae rise to the surface waters, where they remain for several weeks (Scott 1985) feeding principally on planktonic copepods. These larvae are an important food for predators such as Atlantic cod, haddock, pollock and seabirds. The sand lance rises toward the surface at night to feed, returning to the bottom during the day (Scott and Scott 1988).

Adult sand lances are an extremely important food source for many commercial fishes, including Atlantic cod, haddock, American plaice, pollock and yellowtail flounder (Scott and Scott 1988). Because the sand lance is a burrowing fish, it is particularly susceptible to disturbances to the substrate within its range.

Pollock

Mature pollock occur on the slopes of the St. Pierre Bank, which is approaching the northern limit of their range in the Northwest Atlantic (DFO 2002h). Although considered a groundfish, pollock spend much time swimming off the bottom in mid-water. They are not inactive on the bottom, like cod or haddock are at times. With a preferred depth range of 110 to 180 m, pollock have been found at depths to 365 m (Scott and Scott 1988). Spatial analysis of DFO research vessel catch data indicated a decrease in abundance from the early 1990s (most noticeable in 1991) to the late 1990s, with a slight increase from 1998 to 2000 (Kulka et al. 2003).

One-year-old pollock in the Laurentian Channel feed almost entirely on small fishes including herring, sand lance and redfish. Adult pollock eat these same species, as well as crustaceans, in equal proportions, but larger pollock consume more fish than smaller pollock. Pollock have relatively few natural predators, but are sometimes victim to cannibalism, as well as to harbour seals (Scott and Scott 1988). Larval pollock are eaten by a number of predators.

Within the study area, pollock spawn in NAFO regions 3Psg and 3Psh, along the slope of the St. Pierre Bank. Spawning occurs primarily in the late summer and early fall (Murphy 1996).

Porbeagle Shark

The porbeagle is a large cold-water pelagic shark found on the St. Pierre Bank and in the Laurentian Channel during the spring and summer months (Scott and Scott 1988). Porbeagles are ovoviviparous, with an average litter of four pups. Mating occurs in NAFO Division 3Ps in late summer (Campana et al. 2001). Birth occurs eight to nine months later, during the winter in the Northwest Atlantic.

The diet of porbeagles consists of fishes and cephalopods (Campana et al. 2001). In the spring, the diet primarily comprises pelagic species such as herring and mackerel (Scott and Scott 1988), shifting in winter to mostly groundfishes such as haddock. This reflects porbeagle distributions at different times of year, as they move deeper in the fall (Campana et al. 2001).

Redfish

Redfish are primarily a deep water species (Orr et al. 2000), but are reportedly prone to move above the 150 to 200 m depth interval and occasionally as shallow as 100 m (Gomes et al. 1992). Redfish have a complex and variable distribution throughout the year, occupying depths ranging from 100 to 1,400 m. They are stratified by size, with smaller fish in shallow waters and larger fish deeper (McKone and LeGrow 1984).

Redfish occur along the lower slope and in the Laurentian Channel, which is an essential migration route (Breeze et al. 2002). Redfish in Unit 1 (Gulf of St. Lawrence, previously managed as NAFO Divisions 4RST) migrate out of the Gulf of St. Lawrence into the Cabot Strait (specifically subdivisions 3Pn, 4Vn, and 3Ps) from October to December. Due to declining numbers of redfish, areas 3Pn and 4Vn have been closed to fishing during these months since 1995 (Morin et al. 2001; DFO 2000f). Like other migratory fishes, redfish overwinter in the Cabot Strait (DFO 2001e), returning to the upper Gulf of St. Lawrence in the spring.

Spawning occurs in NAFO Divisions 3Ps and 4Vn, along the shelf of the St. Pierre Bank and in the deeper waters of the channel. Mating occurs in late winter and the females carry the developing young until live young are released from April through July (Scott and Scott 1988). After hatching, redfish larvae aggregate in surface waters at the night. During the day, they are found in or below the thermocline at a depth of 10 to 20 m (Fortier and Villeneuve 1996). Success of recruitment is variable, with numerous year-classes observed at intervals at least five years apart, and they require approximately seven years to reach the minimum commercial size (DFO 2000f).

Redfish are pelagic predators, feeding primarily on copepods, amphipods, and shrimp (Rodriguez-Marin et al. 1994), supplemented by capelin in specific areas (Frank et al. 1996).

Due to their declining abundance over the past decade, redfish have been placed on the Prioritized Candidate List by COSEWIC (COSEWIC 2003b).

Rock Grenadier

The rock grenadier is found in the deep waters of the continental slope and abyss, at depths of 350 to 2,500 m, and temperatures of 3.5 to 4.5°C. It undergoes a significant vertical diurnal feeding migration, moving as much as 480 m off the bottom to feed. Its food is primarily pelagic invertebrates and small fishes including crustaceans, euphausiids, and squid. Spawning does not occur within the study area (Scott and Scott 1988).

Rock grenadier are slow swimming fish and are prey for many other fishes including Greenland halibut and redfishes. They are not harvested commercially by Canadian fishermen, but were harvested by USSR fleets in the 1960s through the 1980s (Scott and Scott 1988).

Barndoor Skate

Barndoor skate are not common in the study area, but do occur over parts of the St. Pierre Bank and the Laurentian Channel (Simon et al. 2002). They are found from shoal water up to 750 m. The barndoor skate is the largest species of skate in the North Atlantic, reaching lengths of 152 cm. Mating occurs through internal fertilization, after which the female deposits large egg capsules (12.7 cm long). The

young skate emerges from the egg capsule as a free-swimming individual. Barndoor skate are benthic predators, feeding on bivalve molluscs, squid, shrimp and marine worms. They also feed on fishes such as herring, spiny dogfish, sand lance, hakes and various flatfishes. There are no natural predators, with the exception of very large sharks. No north-south migrations have been observed, but inshore populations have been known to migrate offshore seasonally (Scott and Scott 1988).

Smooth Skate

Smooth skate are found on the St. Pierre Bank and on the slope (McKone and LeGrow 1983), occurring at depths of 45 to 915 m over soft mud and clay bottoms. They concentrate along the shelf edge and the edges of deep basins. Few have been caught on the top of the banks (Breeze et al. 2002). The time of spawning is not known, and it is thought that mating occurs over their entire range. The young skate leaves the egg case as a free-swimming animal (McKone and LeGrow 1983).

The thorny skate and the smooth skate are sympatric species, and compete for the same food sources including decapod crustaceans, mysids and euphausiids (Scott and Scott 1988).

Spinytail Skate

Spinytail skate is the most common deepwater skate in Canadian waters. They are usually found in waters deeper than 165 m, to a maximum of 256 m. Uncommon in the study area, they have been caught on the slope of the St. Pierre Bank. They are known to feed on capelin and spiny skate (Scott and Scott 1988).

Thorny Skate

Thorny skate likely occur throughout the study area, but more commonly in water depths between 90 and 200 m (Gomes et al. 1992), over both hard and soft bottoms (Kulka et al. 1996). They are considered sedentary, rarely moving more than 100 km during their lifetime (Templeman 1984). Spatial analysis of DFO research vessel catch data indicated a continuing reduction in thorny skate density from the late 1980s to the early 1990s (in the northern part of their distribution) (Kulka et al. 2003). Mating, by internal fertilization, takes place year-round (Scott and Scott 1988) throughout the study area on the St. Pierre Bank. Egg cases are released by the female (two per week), and hatching occurs approximately six months later. Young skate leave the egg case as free-swimming fish (McKone and Legrow 1983).

Thorny skate feed on polychaetes, crabs, and whelks and, as they become larger, sculpins, redfish, sand lance and haddock become more important prey items (Rodriguez-Marin et al. 1994). Skate have been found in the stomachs of seals, sharks and Atlantic halibut.

Winter Skate

Winter skate are bottom dwelling fish found on sand and gravel substrates with preferred depth range of 37 to 90 m (Scott and Scott 1988). Within the study area they are found and harvested commercially on the eastern shoal of Banquerueau Bank and the slope waters of NAFO zone 4Vs (DFO 2002k). Reproduction occurs by internal fertilization in the summer and fall. Females deposit demersal egg cases, from which live young emerge. Reproduction likely occurs within the study area, although the precise location is unknown (Scott and Scott 1988).

The diet of the winter skate consists primarily of amphipods and polychaetes. Fishes such as sand lance, decapods, isopods and bivalves are also important food sources. They are preyed upon by sharks, other rays, and grey seals (Scott and Scott 1988).

Spiny Dogfish

Spiny dogfish are small, migratory schooling sharks. They are found on the St. Pierre Bank in June, apparently en route to Placentia, St. Mary's and Fortune Bays (Walsh 1993). These sharks migrate great distances, from Newfoundland to Iceland, New England, and Virginia. Spiny dogfish are ovoviviparous (bearing live young), with a gestation period of 22 to 24 months. All Northwest Atlantic dogfish are considered to belong to a single, large population (Scott and Scott 1988). Birthing occurs during the winter, off the southeastern United States (Walsh 1993), and young are 25 to 30 cm in length at birth (Scott and Scott 1988). Spiny dogfish are opportunistic predators. In the waters off Newfoundland, they feed mainly on small fishes including capelin, herring and Atlantic cod. They have few natural predators. Predaceous bony fishes and sharks prey upon the newly born (Scott and Scott 1988).

Short-Finned Squid

Short-finned squid are pelagic molluscs found from Labrador to Florida. Typically inhabiting deeper waters, they are found along the slopes of the Laurentian Channel during the spring and fall and on the Scotian and St. Pierre Banks during the summer (Breeze *et al.* 2002). With a lifespan of only one and a half years, squid have an extremely high growth rate and only spawn once. Spawning occurs only south of Cape Hatteras during the winter. Larvae are carried north by the Gulf Stream (Breeze *et al.* 2002). There has not been a major commercial squid fishery due to declining stocks, which was caused by prolonged cold waters. Squid prefer bottom temperatures of 9 to 13°C and surface temperatures of 13 to 20°C (Breeze *et al.* 2002).

A voracious predator, squid compete with species such as silver hake for food. They consume fish, crustaceans and molluscs. Squid are an important food source for commercial fish (silver hake, haddock, cod, pollock, and tuna), marine mammals and seabirds (Breeze *et al.* 2002).

Swordfish

Swordfish are a large, migratory pelagic species found worldwide, entering Canadian waters in June and leaving by November and migrating from the warmer Gulf Stream waters offshore (Scott and Scott 1988). During the summer and fall, swordfish can be found throughout the study area. They are found in a large range of depths, from surface waters to deeper than 500 m. They often migrate vertically, preferring deep water during daylight and rising to the surface at night. Reproduction does not occur in Canadian waters (Scott and Scott 1988).

Opportunistic feeders, in Canadian waters swordfish feed on several species of fish, including mackerel, silver hake, redfish and herring, as well as short-finned squid. The only observed predator of swordfish in Canadian waters are sharks (Scott and Scott 1988).

Witch Flounder

Witch flounder have been recorded at depths of 1,570 m, with the greatest numbers occurring at depths between 185 and 365 m. They do not migrate (Scott and Scott 1988). Spatial analysis of DFO research vessel catch data indicated a drop in abundance from the late 1980s to the early 1990s (Kulka et al. 2003). Spawning concentrations of witch flounder have been identified on the southwestern slope of the St. Pierre Bank, and the Esquiman and eastern Laurentian Channel in the Gulf of St. Lawrence (Bowering 1990). Spawning off southwestern Newfoundland and in the northern Gulf of St. Lawrence appears to take place primarily in January and February. Spawning occurs along the slope of the St. Pierre Bank between January and May (Bowering 1996), at depths greater than 500 m where the water temperature is favourable. Fertilized eggs float and hatch within one to two weeks at water temperatures of 8°C. The prey of witch flounders includes polychaete worms, amphipods, small fishes, small bivalves and snails. There is little information regarding predators, but they are known to be food for harp seals (Scott and Scott 1988).

Wolffish

There are three wolffish species that may occur in the deeper waters of the study area.

Northern wolffish occur in the Laurentian Channel (Simpson and Kulka 2001), along the slope of the St. Pierre Bank at intermediate depths of between 90 to 200 m (Gomes et al. 1992), and have been found to depths of 600 m (Scott and Scott 1988). Tagging studies have shown that northern wolffish do not migrate long distances, and do not form large schools. The northern wolffish is a benthic and bathypelagic predator, preying upon jellyfish, comb jellies, crabs, brittle stars, seastars, and sea urchins. Predators of the northern wolffish include redfish and Atlantic cod (Scott and Scott 1988). Due to its declining abundance over its entire range, the northern wolffish was listed by COSEWIC in May 2001 as a threatened species (COSEWIC 2003a).

Spotted wolffish occur in the deep waters of the Laurentian Channel and Hermitage Channel (Simpson and Kulka 2002), at depths of 475 m or more (DFO 2002i). Tagging studies have shown that spotted wolffish only migrate locally, and do not form schools (DFO 2002i). Spatial analysis of DFO research vessel catch data indicated that spotted wolffish abundance declined from the late 1980s to the mid-1990s, with an increase in abundance during both survey seasons since the mid-1990s (Kulka et al. 2003). Its prey includes hard-shelled invertebrates such as crustaceans, molluscs, and echinoderms, and fish, primarily those discarded by trawlers. The species has few predators, although remains have been found in the stomachs of Atlantic cod, pollock and Greenland sharks (Scott and Scott 1988). The spotted wolffish was listed by COSEWIC as threatened in May 2001 (COSEWIC 2003a) because of the decrease in its abundance and distribution in the late 1990s in NAFO Division 3Ps (DFO 2002i).

Atlantic wolffish are found further south than either northern or spotted wolffish, occurring in low numbers at intermediate depths (90 to 200 m) along the slope of the St. Pierre Bank (Gomes et al. 1992), and in the Laurentian Channel during the spring (Simpson and Kulka 2002). They have been found at depths of up to 350 m (Scott and Scott 1988). It is the most abundant wolffish in the study area (DFO 2002i). There is no evidence that Atlantic wolffish migrate long distances, or form schools in Newfoundland waters (DFO 2002i). In the Northwest Atlantic, Atlantic wolffish feed primarily on benthic invertebrates such as echinoderms, molluscs

and crustaceans, as well as small amounts of fish. No predators of adult Atlantic wolffish have been identified, but juveniles have been found in the stomachs of Atlantic cod (Scott and Scott 1988). The Atlantic wolffish was listed by COSEWIC as a species of concern in November 2000 (COSEWIC 2003a).

It is not known with certainty if either of these three wolffish species spawn in the study area, although spawning is probable given the limited migration of the species. If spawning does occur in the Laurentian Subbasin, it would most likely take place on the slope of the St. Pierre Bank, as a colonial activity on underwater ledges. During the late fall fertilized eggs are deposited on either a hard bottom or underwater ledge (Scott and Scott 1988), producing larvae which are large (2 cm long upon hatching) and semipelagic (DFO 2002i).

Yellowtail Flounder

A small population of yellowtail flounder is found on the St. Pierre Bank (Pitt 1983), and there are records of this species as far north as the Strait of Belle Isle. Spatial analysis of DFO research vessel catch data indicated that abundance decreased during spring surveys from the late 1980s to the early 1990s; abundance increased thereafter (Kulka et al. 2003). This is a shallow-water, non-migratory population (Gomes et al. 1992), which is likely sustained by planktonic larvae drifting from spawning grounds on the southern part of the Grand Banks (Pitt 1983). Larvae aggregate in the surface waters (less than 20 m) during the night and move deeper during the day (Fortier and Villeneuve 1996).

Due to the small size of their mouths, yellowtail flounder feed mainly on small benthic polychaete worms and amphipods. They are preyed upon by large fishes such as cod, but specific information on their predators are lacking (Scott and Scott 1988).

3.2.3.2 Species at Risk and Special Areas and Times

As indicated above, five species of fish which are known or likely to occur in the study area have been designated by COSEWIC: Atlantic cod, cusk, northern wolffish, spotted wolffish, and Atlantic wolffish (COSEWIC 2003a).

Atlantic cod occur throughout the study area, including the St. Pierre Bank, Laurentian Channel and Halibut Channel. The primary spawning ground within the study area is the St. Pierre Bank (NAFO areas 3Psf, 3Psg, and 3Psh), with spawning occurring from March to June. Atlantic cod was listed by COSEWIC in April 1998 as a species of special concern in the Atlantic Ocean (COSEWIC 2003a). It was designated as such because it is a species with high reproductive capacity, but which has experienced large declines over the last decade in large parts of its Canadian range and has not shown significant recovery despite a moratorium on fishing.

In May 2003, the Laurentian North population of the Atlantic cod, which extends from the northern Gulf of St. Lawrence to the south coast of Newfoundland (NAFO areas 3Ps, 3Pn4RS), was assessed as threatened. It was noted that cod remain abundant in the eastern part of the region (southern coast of Newfoundland), but have declined substantially in the northern Gulf, where the fishery is now closed. The Maritimes population of the Atlantic cod (NAFO areas 4TVn, 4VsW, 4X, Georges Bank) remains in the special concern category. Portions of each of these stocks overlap with the Laurentian Subbasin area. The Newfoundland and Labrador population of Atlantic cod (NAFO areas 2GH, 2J3KL, 3NO, outside of the study area, see Figure 3.10) was designated as endangered in May 2003 (COSEWIC 2003a).

Cusk were designated as a threatened species by COSEWIC in May 2003. The main population of this large, slow-growing, solitary bottom-living fish inhabits the Gulf of Maine/Southeastern Scotian Shelf, and has been in decline since 1970. Over three generations, the decline rate has been over 90 percent (COSEWIC 2003a). As indicated previously, cusk likely spawn along the southwestern slope of the Laurentian Channel from May to August, with peak spawning occurring in June.

Northern and spotted wolffish were listed by COSEWIC in May 2001 as threatened species in the Atlantic and Arctic Oceans and Schedule 1, Part 3 (Threatened) under the *Species at Risk Act*. Threatened species are those likely to become endangered if limiting factors are not reversed. These wolffish species were listed because their numbers have declined more than 95 percent over three generations and the number of locations where they are found has decreased. Threats to these species include by-catch mortality and critical habitat alteration by bottom-trawlers (COSEWIC 2003a).

The Atlantic wolffish was listed by COSEWIC in November 2000 as a species of special concern in the North Atlantic Ocean and Schedule 1, Part 4 (Special Concern) under the *Species at Risk Act*. Species of special concern are listed as such because of characteristics that make it particularly sensitive to human activities or natural events (COSEWIC 2003a). This species has been designated because its population has been declining since the late 1970s. Possible threats to the Atlantic wolffish include habitat alteration by fishing and possibly environmental changes (COSEWIC 2003a).

Again, it is not known with certainty if either of these three wolffish species spawn in the study area, although spawning is probable given the limited migration of these species. If spawning does occur in the Laurentian Subbasin, it would most likely take place on the slope of the St. Pierre Bank, as a colonial activity on underwater ledges. Wolffish typically spawn in the fall period (September to November).

In addition, a number of fish species found in the Laurentian Subbasin have been placed on COSEWIC's Prioritized Candidate List. This list includes species that are suspected of being in a COSEWIC category but have not yet been examined by the status assessment process. *Group 1* species are those of highest priority for assessment. *Groups 2 and 3* contain species of intermediate and lower priority (COSEWIC 2003b). Fish species that occur in the study area which are included in Group 1 of the Prioritized Candidate List include: northern sand lance, American plaice, Atlantic halibut, smooth skate, haddock, silver hake, pollock, redfish, and white hake (COSEWIC 2003b). Several of these species are known to spawn within NAFO Division 3Ps, inside the study area (Table 3.11).

Redfish, for example, have been placed on the prioritized candidate list by COSEWIC as a result of their declining abundance over the past decade. Redfish are known to occur over the St. Pierre Bank and Laurentian Channel at various depths throughout the year. The Laurentian Channel is known to be an essential migration route and habitat for redfish. During the fall redfish migrate out of the Gulf of St. Lawrence through the Cabot Strait and into the Laurentian Channel where they overwinter, returning to the Gulf of St. Lawrence in the spring. Spawning occurs along the shelf of the St. Pierre Bank and in the deeper waters of the channel. Mating occurs in late winter and the females carry the developing young until live young are released from April through July.

The Canadian *Species at Risk Act* received royal assent in December 2002, and came into force in 2003. The Act is intended to protect species at risk in Canada and their critical habitat. The main provisions of the Act are scientific assessment and listing of species, species recovery, protection of critical habitat, compensation, and permits and enforcement. The Act includes provision for the development of recovery action plans for species that are found to be most at risk, as well as management plans for species of special concern. These plans will be developed by the federal government in consultation with the provinces, territories, wildlife management boards, Aboriginal organizations, industry, and other stakeholders. Once a recovery action plan is in place, it will provide for the protection of critical habitat of that species through conservation agreements, provincial or territorial legislation, or federal prohibitions. The need for specific authorizations for development activities will be clarified through the

development of enabling regulations and species-specific recovery action plans. The potential implications of this new legislation in planning and assessing offshore seismic surveys and drilling programs are discussed in Chapter 5 and Section 6.1.

The Stone Fence is located along the southwestern side of the Laurentian Channel (see Section 3.2.7, Figure 3.8). This feature is recognized as providing habitat for a variety of fish species. Deep-sea coral is also known to occur at the site, which provide habitats for a diverse benthic community. These in turn are an important food source for bottom-dwelling fish species, many of which are of commercial importance. The Stone Fence is also an important fishing area, with wide variety of fish species caught. The Stone Fence is recognized as an area of special ecological and social importance in the general region. In 2002, a few living mounds of *Lophelia pertusa* were recorded on a mostly dead reef in the Stone Fence area. This is the first time that this species has been identified in western Atlantic waters.

In addition, as discussed previously, shelf edges and bank slopes may be highly productive areas, and are therefore often critical locations for spawning and feeding fish, birds and marine mammals. Therefore known and potential areas and times of high productivity (e.g., the western edge of the St. Pierre Bank) are also important aspects of fish and fish habitat in the region.

3.2.4 Marine Birds

This section provides a general overview of marine birds that occur in or near the Laurentian Subbasin, including a description of regularly occurring species and their distribution and abundance. Marine birds that typically occur in the Laurentian Subbasin are pelagic species that occur throughout the year and birds nesting at coastal colonies from late spring through summer. Species composition and abundance in offshore areas, like the Laurentian Subbasin, change seasonally. The south coast of Newfoundland and the coast of Nova Scotia, while outside the boundaries of the Laurentian Subbasin, provides nesting, staging and feeding areas for a variety of marine birds throughout the year. Marine birds are protected under the *Migratory Birds Convention Act*, administered by Environment Canada.

A number of information sources were used to provide a description of the marine birds in the Laurentian Subbasin. The most recent comprehensive compilation of marine bird information for the general area is contained in the *Environmental Assessment of Exploration Drilling off Nova Scotia* (LGL Limited et al. 2000). This report contains a review of marine bird resources in areas between the south coast of Newfoundland and the east coast of Nova Scotia, including the entire Laurentian Subbasin, based on information compiled from:

- the *Gazetteer of Marine Birds in Atlantic Canada* (Lock et al. 1994);
- the *Revised Atlas of Eastern Canadian Seabirds* (Brown 1986);
- *The Birds of Nova Scotia* (Tufts 1986);
- *The Atlas of Breeding Birds of Maritime Provinces* (Erskine 1992);

- *The Researchers Guide to Newfoundland Seabird Colonies* (Cairns et al. 1989);
- local studies on the occurrence of marine birds along southeast Newfoundland in Placentia Bay and Cape St. Mary's (Goudie 1981; Threfall and Goudie 1986; LeGrow 1995);
- aerial and shipboard surveys for marine birds conducted in support of the environmental assessment for the Hibernia Development Project (Williams et al. 1981, Mobil 1985) (which have relevant information for the eastern portion of Laurentian Subbasin); and
- marine bird observation data collected as part of the PIROP program (Program Integri des Recherches sur les Oiseaux Pelagique). The PIROP database is maintained by the Canadian Wildlife Service and contains records of systematic, ship-based bird surveys gathered since 1966 (detailed data are provided in LGL Limited et al. 2000, Appendix 4).

In addition, Breeze et al. (2002) is a recent compilation of existing information. While only a portion of the Laurentian Subbasin area was included in the study area for this overview, the publication does provide relevant regional information on marine birds.

3.2.4.1 Distribution and Abundance

The principal species and groups of marine birds that occur in the Laurentian Subbasin are described in the following sections. The first describes offshore species and their occurrence in the study area. These species or species groups are typically more abundant and have the potential to interact directly with routine activities or accidental events. This is followed by a description of the species groups that tend to occur along the south coast of Newfoundland and the coast of Nova Scotia, either in coastal waters or along the shoreline. Such species could be affected by accidental events that may be associated with offshore activities.

Offshore Marine Birds

Marine birds are often associated with area of upwelling and mixing water masses (Brown 1986). Shallow offshore banks and edges of shelf breaks also tend to be areas where large numbers of birds are found (Lock et al. 1994). These areas tend to support large phytoplankton and zooplankton communities that directly, or indirectly, provide increased foraging opportunities for marine birds.

Fulmars, Shearwaters and Storm-Petrels

Seven species of marine birds in this group may occur in the Laurentian Subbasin. These include:

- northern fulmar;
- greater shearwater;
- sooty shearwater;
- Cory's shearwater;

- manx shearwater;
- Wilson's storm-petrel; and
- Leach's storm-petrel.

The northern fulmar is a common year-round resident that nests in small numbers in eastern Newfoundland, outside of the Laurentian Subbasin (Brown 1986). Most fulmar nesting occurs in the Arctic, and the species is most abundant in the Laurentian Subbasin during the winter and early spring. During winter, fulmars are common in shallow bank areas (Breeze et al. 2002) and may be expected to occur on the St. Pierre Bank.

Shearwater are predominantly found in the study area in summer, and are most abundant from June through August (Brown 1986). Greater and sooty shearwater nest in the southern hemisphere and spend the southern winter in North Atlantic waters. Cory's shearwater nest in the eastern North Atlantic and may also be present in the Laurentian Subbasin during summer, although they tend to occur in waters influenced by the warmer Gulf Stream (Brown 1986). At least 5 million greater shearwater, and lesser numbers of sooty shearwater, are found in the summer from Georges Bank to southern Greenland. Congregations of shearwater are found both offshore and inshore, with large numbers being documented in coastal bays (Brown 1986). Cory's and manx shearwaters are observed regularly in small numbers on the Scotian Shelf (Tufts 1986). Manx shearwater are known to breed on Middle Lawn Island off the south coast of the Burin Peninsula, the only confirmed nesting location in North America.

Most of the North Atlantic population of Leach's storm-petrel (greater than 1 million birds) nest in Newfoundland, with approximately 300,000 pairs nesting on islands off the south coast of Newfoundland. In recent years, the number of Leach's storm-petrels has been reduced due to gull predation along the Atlantic coast. However, there are indications that breeding populations are increasing (Breeze et al. 2002). Wilson's storm-petrel may occur in the Laurentian Subbasin, but the largest numbers occur at the mouth of the Bay of Fundy and Georges Bank (Tufts 1986).

Northern Gannet

Approximately 5,500 pairs of northern gannets nest on the south coast of Newfoundland at Cape St. Mary's, east of the Laurentian Subbasin (Cairns et al. 1989). Outside of the breeding season, northern gannets are largely pelagic and are not likely to be found in the Laurentian Subbasin except during spring and fall as they move between inshore and offshore areas. This species does not tend to congregate in large groups, but rather, occur in small aggregations. While all marine birds are susceptible to oiling, northern gannets may be less vulnerable than some other species as they spend less time sitting on the water and feed by plunging through the surface from the air (LGL Limited et al. 2000).

Gulls, Terns and Jaegers

Herring gulls and great black-backed gulls are common and can be found in the study area throughout the year. Other less common gull species that may be present in fall, winter, and spring include glaucous gull, Iceland gull, and ivory gull. The ivory gull, listed as a species of special concern by COSEWIC, may occur along the edge of pack ice in the winter. Black-legged kittiwakes are pelagic in winter but breed at Cape St. Mary's (10,000 pairs) and at the Bird Islands of Cape Breton (1,456 pairs) (LGL Limited et al. 2000). During summer, kittiwakes tend to remain near breeding colonies (Breeze et al. 2002). A reduction in fishing activity in Atlantic Canada has caused diet changes in gulls, particularly great black-backed gulls and herring gulls. As a result, great black-backed gulls are affecting breeding success of kittiwakes and puffins in Newfoundland by preying more heavily on the chicks of these species (Tasker et al. 1999b, cited in Breeze et al. 2002).

Arctic and common terns are present in the Laurentian Subbasin area in the spring and summer months, and are known to nest at approximately 50 sites along the south coast of Newfoundland and along the Nova Scotia coast and Sable Island. Terns migrate south for the winter. Other species of terns that may occur infrequently in the Laurentian Subbasin area include caspian tern, that nest in Newfoundland (Canadian Wildlife Service – Atlantic, unpublished data), and the roseate tern.

Roseate terns, listed as endangered by COSEWIC, breed in small numbers in Nova Scotia, in colonies of other tern species. The population for Canada has been estimated at 86 to 130 pairs (Whittam 1999) with more than 30 pairs breeding at Country Island (Twolon and Nadeau 1998). Other breeding sites include The Brothers Islands, Grassy and Westhaver Islands and Sable Island. In 2000, four roseate terns were found nesting on Sable Island, although only one pair was found nesting in 2001 (Horn and Taylor 2000; Taylor et al. 2001). The reduction of roseate terns is of concern since, in both 2000 and 2001, the high mortality of eggs and young was positively correlated to the proximity of gull colonies and numbers of hunting gulls observed at the tern colony.

Similar to northern gannets, gulls and terns may be less vulnerable to oiling as they spend less time sitting on the water than other species.

Jaegers, which breed in the southern hemisphere, spend the austral winter in North Atlantic waters, primarily offshore (Brown 1986).

Alcids

Six species of alcids may be found in the Laurentian Subbasin, with most generally occurring outside of the nesting season. The alcid group is comprised of common and thick-billed murres, razorbills, dovebies, Atlantic puffin, and black guillemot. Alcids, particularly murres, are likely the group most vulnerable to oil pollution as they spend considerable time sitting on the water (Montevecchi et al.

1999). Over 10,000 pairs of common murres and lesser numbers of thick-billed murres, razorbills, and black guillemots nest at Cape St. Mary's. Common and thick-billed murres are most abundant during the winter, although they may be found year-round in the Laurentian Subbasin area. The Atlantic puffin breeds in relatively small numbers along the south coast of Newfoundland and on the Bird Islands and Pearl Island off Nova Scotia. It is observed during fall and winter, although less frequently than common and thick-billed murres. Similarly, razorbills are less common residents outside of the breeding season. Dovekies spend the winter months in the offshore and coastal areas of Newfoundland and Nova Scotia, and may use coastal bays in large numbers (Threfall and Goudie 1986). Like petrels, dovekies are often associated with topographical features such as shelf breaks where foraging opportunities are maximized (Breeze et al. 2002).

Coastal and Nearshore Marine Birds

Loons and Grebes

Loons and grebes generally occur in low numbers in the study area. However, during migration, relatively large numbers may pass through the Laurentian Subbasin. Two species, red-throated loon and common loon, may be found in the study area during spring and fall, occurring in coastal and nearshore waters (LGL Limited et al. 2000). Horned grebe and red-necked grebe exhibit similar distributions and large concentrations of red-necked grebes (400 to 600 individuals) have been observed in St. Pierre and Miquelon (Threfall and Goudie 1986).

Cormorants

The great cormorant and double-crested cormorant can occur in the Laurentian Subbasin, and west along the south coast of Newfoundland. The great cormorant is a year-round resident in the marine environment, while the double-crested cormorant migrates away from the region during the winter and may use freshwater areas for breeding. Cormorants are more numerous in Nova Scotia than in coastal Newfoundland waters. There are approximately 6,000 pairs of great cormorants in Canada (Bird Life International 2001), and thousands of pairs breed in colonies along the south coast of Nova Scotia and the eastern Cape Breton Islands (Tufts 1986). In contrast, only about 110 pairs of great cormorants and 140 pairs of double-crested cormorants nest along the south coast of Newfoundland and at St. Pierre and Miquelon (Cairns et al. 1989).

Waterfowl

Various species of waterfowl occur in the marine waters off the east and south coasts of Newfoundland. For many species, breeding occurs on freshwater bodies inland and marine waters are used for spring and fall staging and overwintering. Waterfowl are often found in large congregations in marine waters during these non-breeding periods.

Common eiders, scoters, long-tailed duck, and mergansers are common coastal wintering species. The greatest concentration of waterfowl occurs around Cape St. Mary's and in Placentia Bay, to the east of the Laurentian Subbasin. In particular, large numbers of common eiders have been recorded in the Placentia Bay area (Goudie 1981). The area from Cape Race to Cape St. Mary's and the Islands of St. Pierre and Miquelon also have large wintering populations of common eiders. Other less common species include American black duck, greater scaup, and common goldeneye. The coastline of Nova Scotia also provides extensive nesting and moulting and overwintering habitat for these species (LGL Limited et al. 2000).

Since most waterfowl species nest inland (i.e., Canada goose, American black duck, mallard, northern pintail, blue-winged teal, green-winged teal, common merganser), there is little or no interaction with the marine environment during the summer. However, common eider tend to nest on coastal islands, and may be found in the study area. Nests of this species are relatively uncommon along the south coast of Newfoundland with only 22 pairs identified at four sites by Caines et al. (1989). Common eiders nest in greater numbers along the coast of Nova Scotia, with approximately 8,000 pairs occurring at coastal sites along southwestern and eastern Nova Scotia (Erskine 1992).

Harlequin ducks are listed as a species of special concern by COSEWIC. The species occurs off Cape St. Mary's during the winter and may number over 100 birds in some years (LGL Limited et al. 2000).

Shorebirds

A variety of shorebird species occur in or near the study area, primarily as migrants foraging along the coastline prior to moving to wintering or breeding habitat. Large numbers of migrating shorebirds do not occur along the east and south coast of Newfoundland, as suitable foraging habitat is limited. However, at selected sites with suitable habitat (i.e., Little Lawn Harbour on the Burin Peninsula), small flocks of migrating shorebirds do occur regularly. In contrast, the Atlantic coast of Nova Scotia may host flocks of up to 20,000 birds in areas with extensive mudflats (LGL Limited et al. 2000).

Several pairs of piping plovers, listed as endangered by COSEWIC, are known to nest along the south coast of Newfoundland at Burgeo and Port aux Basques (approximately 200 km and 300 km northwest of the Laurentian Subbasin, respectively), along the coast of Nova Scotia, and on Miquelon (LGL Limited et al. 2000).

Other Species

Bald eagle and osprey are found in coastal marine areas, often nesting along the shore. The bald eagle is a year-round resident and groups of individuals often congregate along open bays of the south coast of Newfoundland in winter. Osprey migrate to the southern United States and into South America during the winter.

3.2.4.2 Species at Risk and Special Areas and Times

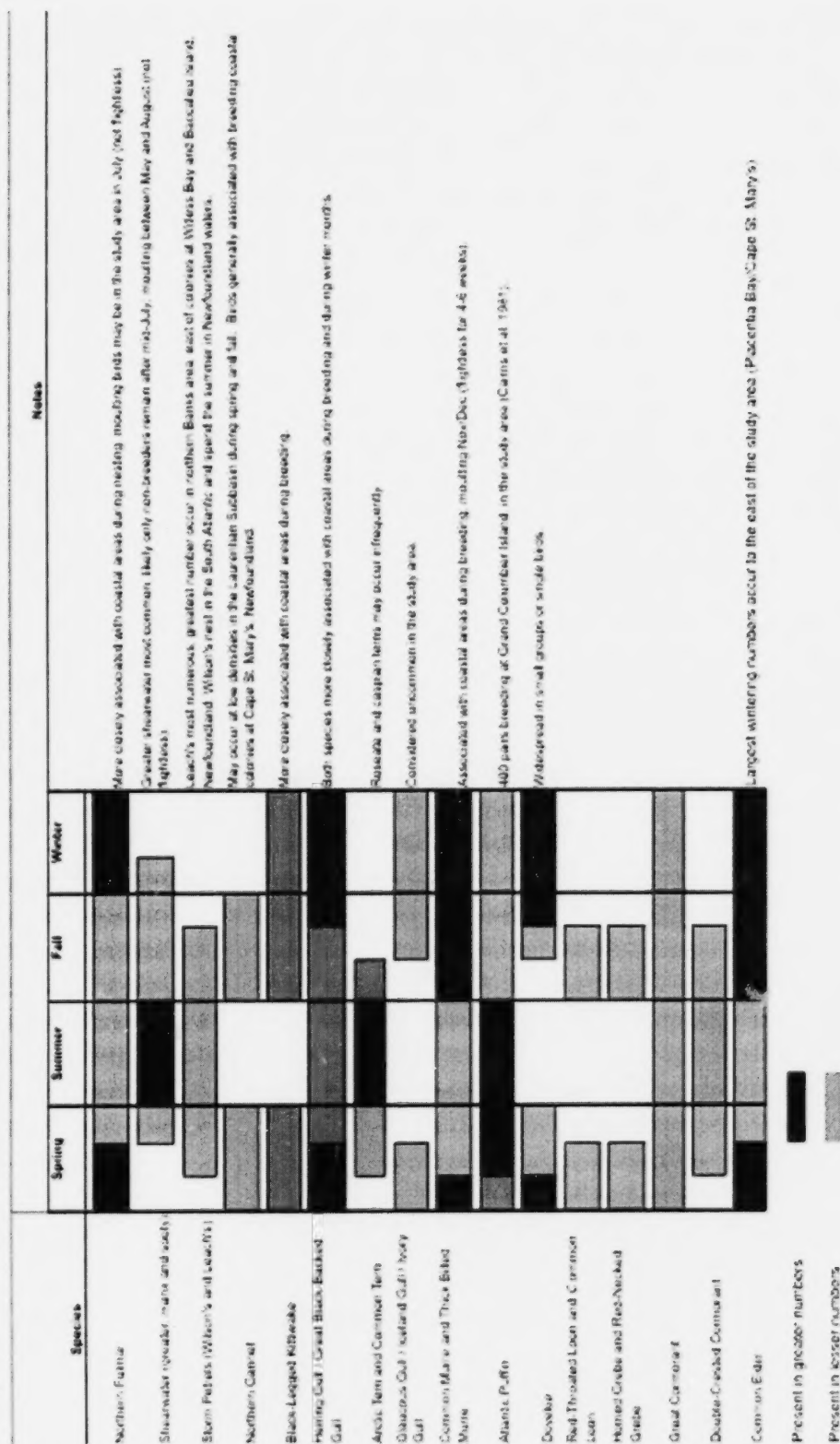
The Laurentian Subbasin and nearby shorelines and adjacent water provide habitat for large numbers of marine birds throughout the year, with many species moving in and out of the area at different times. A summary of the likely seasonal occurrences of marine birds on and near the Laurentian Subbasin is presented in Figure 3.6. Large numbers of species that nest in the Southern Hemisphere spend the austral winter in offshore North Atlantic waters during the summer and early fall. The largest groups are the shearwaters and Wilson's storm petrels. Large numbers of these birds may be using the offshore waters of the Laurentian Subbasin and surrounding areas, although there is little ability to predict the distribution and abundance of species at any given time. Large numbers of common and thick-billed murre and other alcids winter in offshore waters. Populations of overwintering waterfowl, including harlequin duck and large numbers of common eider, occur along the south coast of Newfoundland and the eastern shore of Nova Scotia. As noted above, the distribution and abundance of wintering populations are difficult to predict for any given time.

The Cape St. Mary's area is important to several species of nesting marine birds, including northern gannets, black-legged kittiwakes, and common murre. Several islands near the Burin Peninsula are the sites of large Leach's storm-petrel colonies. Common eiders nest in large numbers at sites along the southwestern and eastern shores of Nova Scotia. Small numbers (22 pairs) nest at four sites along the south coast of Newfoundland (Cairns et al. 1989).

The locations of seabird colonies and other important bird sites adjacent to the study area are illustrated in Figure 3.7. Cape St. Mary's hosts over 5,000 breeding pairs of northern gannets, 10,000 pairs of black-legged kittiwakes, and 10,000 pairs of common murre (Cairns et al. 1989). Middle Lawn Island, off the Burin Peninsula, provides nesting habitat for over 25,000 pairs of Leach's storm petrels while Grand Columbiar Island, off St. Pierre and Miquelon supports 100,000 pairs (Cairns et al. 1989). In Nova Scotia, the Pearl and Bird Islands support breeding populations of Atlantic puffins, razorbills, Leach's storm petrels, and black-legged kittiwakes (Breeze et al. 2002). Seal Island and the Tusket Island Group, off the south coast of Nova Scotia, are important migratory bird stopover sites as well as breeding sites for large populations of birds (Breeze et al. 2002) (Figure 3.7).

Several species that have special conservation status can occur in the Laurentian Subbasin or along the south coast of Newfoundland or off Nova Scotia. The harlequin duck (of special concern under Schedule 1, Part 4 of the *Species at Risk Act*) occurs off Cape St. Mary's and along the southern and eastern shores of Nova Scotia in winter (Figure 3.7). The piping plover (endangered under Schedule 1, Part 2 of the *Species at Risk Act*) nests at beaches near Burgeo and Port aux Basques, Newfoundland, along the coast of Nova Scotia and on the island of Miquelon in summer. The roseate tern (endangered under Schedule 1, Part 2 of the *Species at Risk Act*) breeds in small numbers on Country Island and Sable Island off the coast of Nova Scotia (Figure 3.7). The ivory gull (of special concern under Schedule 1, Part 4 of the *Species at Risk Act*) is an uncommon winter vagrant and is usually associated with pack ice.

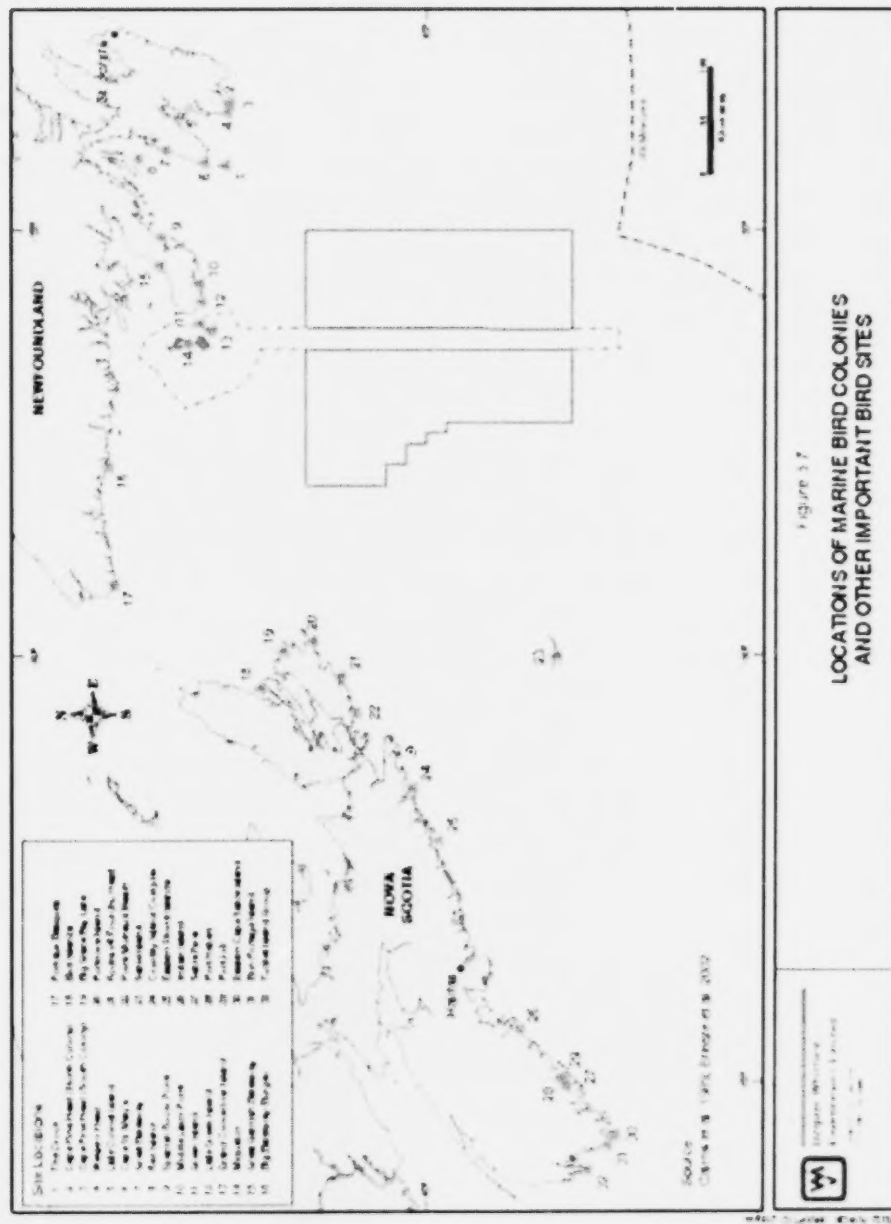
Figure 3.6 Seasonal Occurrences of Marine Birds in the Study Area
Figure 3.6 Seasonal Occurrences of Marine Birds in the Study Area



Present in greater numbers
 Present in lesser numbers

Sources: Broeze et al. (2002)
 LGL Limited et al. (2000)
 Huellmann and Darrood (2000)
 Brown (1996)

Figure 3.7 Locations of Marine Bird Colonies and Other Important Bird Sites



As discussed in Section 3.2.3.2, the Canadian *Species at Risk Act* received royal assent in December 2002, and came into force in 2003. The Act is intended to protect species at risk in Canada and their critical habitat. The potential implications of this new legislation in planning and assessing offshore seismic surveys and drilling programs are discussed in Chapter 5 and Section 6.1.

3.2.5 Marine Mammals

3.2.5.1 Whales and Dolphins

A number of species of whales and dolphins (cetaceans) are known or expected to occur in the general region of the Laurentian Subbasin. These are listed in Table 3.12, along with the population status of those that have been categorized by COSEWIC (2003a) and under the *United States Endangered Species Act* National Marine Fisheries Service ((NMFS) 2002a). More information on the regional status of each species is presented in the text which follows.

Table 3.12 Cetaceans Known or Expected to Occur in the Laurentian Subbasin

SPECIES		COSEWIC Status	US <i>Endangered Species Act</i> Designation
Common Name	Scientific Name		
Northern Right Whale	<i>Eubalaena glacialis</i>	Endangered (Species)	Endangered (Species)
Minke Whale	<i>Balaenoptera acutorostrata</i>		
Fin Whale	<i>Balaenoptera physalus</i>	Special Concern (Atlantic)	Endangered (Species)
Blue Whale	<i>Balaenoptera musculus</i>	Endangered (Atlantic)	Endangered (Species)
Sei Whale	<i>Balaenoptera borealis</i>	Data Deficient (Atlantic)	Endangered (Species)
Humpback Whale	<i>Eubalaena glacialis</i>	Not at Risk	Endangered (Species)
Sperm Whale	<i>Physter macrocephalus</i>	Not at Risk	Endangered (Species)
Beluga Whale	<i>Delphinapterus leucas</i>	Endangered (St. Lawrence)	
Northern Bottlenose Whale	<i>Hyperoodon ampulatus</i>	Endangered (Scotian Shelf)	
Sowerby's Beaked Whale	<i>Mesoplodon bidens</i>	Special Concern (Atlantic)	
Killer Whale	<i>Orcinus orca</i>	Data Deficient (NW Atlantic)	
Long-Finned Pilot Whale	<i>Globicephala melaena</i>	Not at Risk	
White-Beaked Dolphin	<i>Lagenorhynchus albirostris</i>	Not at Risk	
Atlantic White-Sided Dolphin	<i>Lagenorhynchus acutus</i>	Not at Risk	
Short-Beaked Common Dolphin	<i>Delphinus delphis</i>	Not at Risk	
Bottlenose Dolphin	<i>Tursiops truncatus</i>	Not at Risk	
Striped Dolphin	<i>Stenella coeruleoalba</i>	Not at Risk	
Harbour Porpoise	<i>Phocoena phocoena</i>	Special Concern (NW Atlantic)	Candidate (Gulf of Maine)

NMFS (2002b) provides information on the distributions, abundances, seasonality and conservation status of individual cetacean species in the Northwest Atlantic. Whitehead et al. (1998) and Breeze et al. (2002) are further sources of information for marine mammals on the Scotian Shelf.

However, there is virtually no published information on the presence of cetaceans within the Laurentian Subbasin area itself, apart from the following plotted sightings: two humpbacks reported by Sergeant (1966); several sei whales in Mitchell and Chapman (1977); and a few (possibly group sizes) of common and white-sided dolphins in Palka (2001).

A large database of cetacean sightings in the broader region, including the Laurentian Subbasin, is currently being developed by DFO, but is unavailable at the time of writing. Accordingly, at this point it is possible only to consider the probable status of cetaceans within the Laurentian Subbasin area largely from information for other regions.

Mitchell (1977) gives tagging positions of 672 whales off Nova Scotia and Newfoundland and Labrador. Of these, none were apparently tagged within the Laurentian Subbasin area (out of 286 fin, 190 humpback, 109 sperm, 30 sei, 22 blue, 12 minke, 8 northern right, 7 pilot, 6 killer, and 2 northern bottlenose whales). This appears to suggest that the study area is at least not a major concentration zone for whales relative to the whole of Atlantic Canada.

Records of past whaling in the region give some insight into presence of large whales in the general study area. The most up-to-date overview of whaling in the area is by Sanger and Dickinson (1995), who summarize the operations of 20th century whaling stations in Newfoundland. They note that 6 of 16 of these stations were located along the island's south shore. Sergeant (1966) enumerates kills out of these southern shore stations during 1906 to 1914 (97 blue and 66 humpback whales) and Sanger and Dickinson (1995) tabulate those out of a station in Placentia Bay during 1927 to 1936 (335 fin, 80 blue, 35 sei, 24 humpback and five sperm whales). Although the precise locations of these kills is not known, some could have occurred within the study area. However, the only mapped positions of kills apparently available (seven blue whales killed in or near Placentia Bay, 1941-1946; Sergeant 1966), suggest that these whalers operated primarily in waters closer to the south coast of Newfoundland.

Of some relevance are estimates of minimal population densities (uncorrected for times underwater) based on aerial surveys of the eastern Scotian Shelf and the Gulf of St. Lawrence (Table 3.13). Although the overall accuracy of the survey information is uncertain, it does permit comparisons between these two regions. Apart from the minke whale and harbour porpoise (both of which are known to frequent inshore waters and only occasionally wander to deeper, offshore waters), cetaceans appeared much more thinly spread in the Gulf than on the eastern Scotian Shelf. However, it cannot be inferred that cetaceans in the Laurentian Subbasin may be found in approximately intermediate densities. There are two main reasons for this: 1) because both the Gulf and the Eastern Scotian Shelf have areas where cetaceans are concentrated, the overall estimates may be misleading if such concentration also occur in the Laurentian

Subbasin, and 2) some species are known to migrate via the Cabot Strait to spend the ice-free season in biologically rich areas of the Gulf, and may or may not spend much time passing through the Laurentian Subbasin.

Table 3.13 Densities of Cetaceans on the Eastern Scotian Shelf and Gulf of St. Lawrence

Species	Eastern Scotian Shelf		Gulf of St. Lawrence	
	Density (per km ²)	Coefficient of Variation (CV)	Density (per km ²)	Coefficient of Variation (CV)
Fin Whale	0.0071	0.76	0.0019	0.79
Humpback Whale	0.0074	0.74	0.0006	0.42
Minke Whale	0.0023	0.47	0.0052	0.27
Sperm Whale	0.0006	1.06	0	--
Long-Finned Pilot Whale	0.0323	0.57	0.0082	0.65
Atlantic White-Sided Dolphin	0.2588	0.54	0.1236	0.47
White-Beaked Dolphin	0	--	0.0135	0.79
Short-Beaked Common Dolphin	0.0130	0.98	0	--
Bottlenose Dolphin	0.0156	0.76	0	--
Harbour Porpoise	0	--	0.1274	0.26
Unidentified Medium and Large Cetacea	--	--	0.0001	--
Unidentified Small Cetacea	--	--	0.0001	--

Note: Densities per km² of cetaceans based on 1995 aerial surveys on the eastern Scotian Shelf (from Table 4 in Palka 2001) and Gulf of St. Lawrence (from Tables 2, 8 in Kingsley and Reeves 1998, Table 2, 8). These are minimal estimates, uncorrected for the proportions of time spent underwater by various species.

Despite the paucity of direct information on cetacean populations in the Laurentian Subbasin, its deep channel running to the shelf break with its flanking banks clearly supply a mix of environmental conditions known to be important for cetacean populations elsewhere in the western North Atlantic.

Hamazaki (2002) developed "habitat prediction models" for cetacean species in the region between North Carolina and southern Nova Scotia, showing that some species favour the nearshore (e.g., minke whale, harbour porpoise, white-sided dolphin), others the shelf (e.g., fin, humpback and pilot whales, common dolphin), and others the offshore area (e.g., sperm whale). Hamazaki's (2002) plotted observations indicated, however, that most fin whales, sperm whales, common dolphins, and pilot whales (especially in fall-winter) were in fact concentrated at and beyond the shelf break.

A more regionally pertinent indication of the importance of deeper waters along the shelf break is Whitehead et al.'s (1998) demonstration that relative abundances (sightings per hour) of all but two cetaceans (minke whale and harbour porpoise) were substantially higher in The Gully than in other areas of the eastern Scotian Shelf. Sutcliffe and Brodie (1977) noted that high production and plankton densities may support the concentration of baleen whales along the Scotian Shelf slope. Copepods (McLaren et al. 2001) and euphausiids (Sameoto and Cochrane 1996), on which baleen whales may feed, are known to concentrate in the deeper waters of the Scotian Shelf basins and off the shelf break.

Some larger toothed whales dive deeply to feed on squids and fishes. Clearly the Laurentian Subbasin and its surrounding area offer a range of suitable habitats for a variety of cetacean species.

Additional information on the individual species in Tables 3.12 and 3.13 can be derived from a variety of sources. It should be remembered that most of the "best estimates" (NMFS 2002b) of population sizes in the species accounts that follow are from aerial survey data, uncorrected for dive times, and are accordingly minimal. Without more detailed information on marine mammals presence and movements within the study area, it is not currently possible to map the distributions or seasonal migrations of individual species within the Laurentian Subbasin and nearby regions. The available information is summarized in the following text.

The following sections provide an overview of those whales and dolphins which are known or expected to occur within the study area. As indicated in Table 3.12, 11 of 18 cetaceans known or likely to occur in the area and one seal are listed by COSEWIC and/or NMFS or both, and may therefore be considered species at risk. A discussion of each of these species is included within the following text.

The endangered **northern right whale** (COSEWIC 2003a) has a total population of approximately 300 based on resightings analysis (NMFS 2002b), and its endangered status is well known. In Canadian waters, it spends summers primarily in the Bay of Fundy and on the western Scotian Shelf (Breeze et al. 2002). It could also occur rarely in the Laurentian Subbasin area, as indicated by its former presence in, and occasional more recent wanderings to, Newfoundland (Sergeant 1966) and the Gulf of St. Lawrence (Kingsley and Reeves 1998). As a north-south migrant species, any rare wanderings through the Laurentian Subbasin would be most likely from spring through late summer, and individuals could conceivably pause to feed on the large concentrations of descended *Calanus* copepods known to occur in the channel (Zakardjian et al. in press).

The **minke whale**, the smallest baleen whale in the region, tends to feed on schooling pelagic fishes and smaller groundfishes. It is considered to be a "Canadian East Coast stock," with a "best estimate" of 4,018 (coefficient of variations (CV) 0.16) individuals, by NMFS (2002a), which does not consider that human-related mortalities require listing it as a "strategic stock". It is mapped by NMFS (2002b) as concentrated inshore the Gulf of Maine, Bay of Fundy, and southwest Nova Scotia, and described as "largely absent" from those areas during winter. Breeze et al. (2002) map it as also "of probable regular occurrence" throughout the Scotian Shelf. In the nearby Gulf of St. Lawrence (Kingsley and Reeves 1998), most aerial sightings were on shelf and inshore areas. Although there are no published observations of it in the Laurentian Subbasin, it likely occurs there, especially as spring and fall migrants between the Scotian Shelf and Gulf of St. Lawrence, and mostly on the flanking banks.

The **fin whale** is the most abundant large whale in the general region, its numbers augmented in summer by migration from more southern waters. The Northwest Atlantic Stock occurs mostly over deeper basins and shelf slopes from the northeastern US to southeastern Newfoundland, with a "best estimate"

population size in that region of 2,814 (CV 0.21) per NMFS (2002a). Because human-caused mortality is estimated to be greater than 10 percent of the extremely conservative potential biological removal (PBR) assumed for endangered species, it is rated as a "strategic stock" by NMFS (2002b). It is mapped by Breeze et al. (2002) as of "known regular occurrence" in Roseway Basin, the Gully region, and southwest of Sable Island Bank, and "of probable regular occurrence" throughout the Scotian Shelf to about the middle of Banquereau Bank. Beyond this, they are known to migrate into and out of the Gulf, within which they are associated with the steep contours of the Laurentian Channel (Sergeant 1977; Kingsley and Reeves 1998). This species undoubtedly migrates regularly through the Laurentian Subbasin area (especially in the Laurentian Channel) in spring and fall, with some lingering as summer residents. The fin whale is listed as being of special concern by COSEWIC (2003a).

The **blue whale** is the largest baleen whale, with a western North Atlantic stock largely in Canadian waters, but extending south of northeastern United States in winter (NMFS 2002a). A total of 308 individuals were photographically identified in the Gulf of St. Lawrence up to 1988 (Sears et al. 1990), but these cannot be used to estimate total population size (Hammond 1988). The "level of human-caused mortality and serious injury is believed to be insignificant," but its endangered status mandates its designation as a "strategic stock" (NMFS 2002a). It is particularly dependent on euphausiids and hence deeper waters where this food species is concentrated (Sutcliffe and Brodie 1977). It is mapped by Breeze et al. (2002) as of "known" or "probable regular occurrence" near channels and basins in the western Scotian Shelf, and as migrating along the shelf break to the northeast and into the Laurentian Channel. Although only five were spotted in aerial surveys of the of St. Lawrence in 1995 and 1996 (Kingsley and Reeves 1998), it is known to migrate into and out of the Gulf of St. Lawrence and photographs taken in the Gulf have been matched to some taken in the Gulf of Maine and West Greenland (Kingsley and Reeves 1998). It is possible that a measurable proportion of the western North Atlantic stock of blue whales passes through or pauses in the Laurentian Subbasin, mostly in the deeper parts and primarily during spring, summer and fall. Whaling statistics indicate that it can also occur inshore off southern Newfoundland (Sergeant 1966), where it is also known to occur in winter (Mansfield 1985). The Atlantic population of blue whale is also listed as endangered by COSEWIC (2003a).

The **sei whale** is a temperate species appearing in the region in summer, and consuming mostly copepods and euphausiids. Its population was estimated by tag-recaptures as being between 1,393 and 2,248 individuals by Mitchel and Chapman (1977), but there are no recent estimates (NMFS 2002b). The level of human-related mortality is suggested to be "insignificant", but its endangered status mandates designation as a "strategic stock" (NMFS 2002a). In May 2003, the Atlantic population of sei whale was designated as "data deficient" by COSEWIC (COSEWIC 2003a). During the summer feeding season, it may be mostly concentrated off the banks of the Scotian Shelf, where individual sightings (Mitchell and Chapman 1977) are clustered off southwest Nova Scotia along the shelf break and around The Gully, and in and around the Laurentian Subbasin. Off Nova Scotia, more sei whale kills were often distributed closer to the 2,000 m depth contour than were fin whales (Mitchell 1977). In some

summers, there are incursions into shallower and inshore waters (NMFS 2002b). Based on such evidence, Breeze et al. (2002) map the species as of "known" or "probable regular occurrence" in basins of the eastern Scotian Shelf and along the shelf break. It is possible that the sei whale is more frequent during summer in the deeper parts of the Laurentian Subbasin than might be suggested by its general status off Atlantic Canada.

The "best estimate" of the population size of the **humpback whale** in the North Atlantic is 10,600 (CV 0.067), of which perhaps only 1,100 may occur in the northeastern parts (NMFS 2002b). Although it is believed to be increasing, its endangered status and a level of human-caused morality and serious injury rated as "significant", mandate continuing designation as a "strategic stock" (NMFS 2002a). In May 2003, the western North Atlantic population of the humpback whale, previously listed in the special concern category by COSEWIC, was removed from the list due in part to the success of recovery efforts (COSEWIC 2003a). Its piscivorous diet associates it with schooling pelagic fishes in both deep and shallow waters. Understanding of stocks of humpback whales in the western North Atlantic is a subject of recent discussion and revision. They may occur in four genetically distinct "feeding stocks," but with some exchange among them (NMFS 2002b): in the Gulf of Maine, Gulf of St. Lawrence, Newfoundland and Labrador, and West Greenland. The species is characterized by Breeze et al. (2002) as "known" to summer in a large area southwest of Sable Island Bank and around The Gully, and of "probable regular occurrence" in the outer half of the Scotian Shelf to about the middle of Banquereau Bank. Whitehead et al. (1998) document sightings from The Gully between May and November. However, the species was quite rare in aerial surveys in the Gulf of St. Lawrence (Table 3.13), mainly along the Québec North Shore and Strait of Belle Isle (Kingsley and Reeves 1998). A somewhat different view is presented by the International Whaling Commission (2002), in which only two principal feeding grounds are plotted in the Gulf of Maine and Bay of Fundy, and off the south and east coasts of Newfoundland and north to northern Labrador. The latter feeding grounds are shown as extending onto northeastern part of the Laurentian Subbasin. Waring et al. (2002) suggest that the humpback whale population of the Scotian Shelf is larger than previously thought. A large whale survey conducted in 2002 (Clapham and Wenzel 2002) indicated that the humpback whale was the most common mysticete on the eastern Scotian Shelf, with major concentrations found on the northern edge of the Banquereau Bank in the Stone Fence area.

The **sperm whale**, the largest toothed whale, is known throughout much of the world, including eastern Canada from the Bay of Fundy to at least northern Labrador (Mitchell 1974). The "best estimate" of the western North Atlantic population is 4,702 (CV 0.36) per NMFS (2002a). Although the human-caused morality of this population is rated as "insignificant", it remains "strategic stock" because of its continued listing as "endangered" (NMFS 2002b). The Canadian population is comprised of almost all males (Mitchell 1974; Reeves and Whitehead 1997). Although there is some withdrawal southward in winter (NMFS 2002b), some occur throughout the year as evidenced by winter strandings on Sable Island (Lucas and Hooker 2000). High densities were found along the edge of the eastern Scotian Shelf, and especially in The Gully, by Whitehead et al. (1992), and the species is plotted as of "probable regular occurrence" along the edges of the Scotian Shelf and into the Gulf of St. Lawrence along the

Laurentian Channel by Breeze et al. (2002). Sperm whales were recorded to the east of the Stone Fence in the Laurentian Channel during a 2002 large whale survey (Clapham and Wenzel 2002). However, it was not observed in aerial surveys in the Gulf (Kingsley and Reeves 1998). Despite this possible contradiction in perceived distribution, the slopes and deep waters of the entrance to the Laurentian Channel appear to be a suitable environment for sperm whales, which are therefore expected in the Laurentian Subbasin area (perhaps more commonly than other large whales), mostly in summer but probably at all times of year.

The endangered population of **beluga whale** (COSEWIC 2003a) in the lower St. Lawrence River is found mostly upstream from the Gulf proper, and it was not detected there in the 1995 aerial survey (Kingsley and Reeves 1998). Because extralimital strays to Atlantic Canada have included a known individual from this population (Brown Gladden et al. 1999), there is a possibility that an occasional beluga could stray to the Laurentian Subbasin, possibly at any time of the year.

The status of Scotian Shelf population of **northern bottlenose whale** (formerly listed as The Gully population) has been elevated to "endangered" (COSEWIC 2003a). This population of approximately 130 animals is known to range along the slope of the northeastern Scotian Shelf between about the western end of Sable Island and the middle of Banquereau Bank (Breeze et al. 2002), of which approximately 40 occur at any one time in The Gully (Gowans et al. 2000). The limits of distribution of this population, and the possible occurrence of other populations along the edge of Scotian Shelf, have not been fully explored. The species is known to have occurred from the southern edge of the Grand Banks to at least northern Labrador (Mitchell 1974), and individuals have wandered to the Gulf of St. Lawrence (Kingsley and Reeves 1998). The northern bottlenose whale is obviously potentially a species of primary concern in the Laurentian Subbasin. Although there appears to be no record of it from the area, there would appear to be suitable habitat along the slopes and depths of the channel and it could occur at any time of year.

Sowerby's beaked whale is listed by COSEWIC (2003a) as of special concern (Table 3.12). Its population size, mortality rates, etc., are virtually unknown, but it is listed along other beaked whales as a strategic stock by NMFS (2002b). It has been sighted in The Gully (Baird and Hooker 1999), has stranded on Sable Island (Lucas and Hooker 2000), and occurs considerably farther north (Lien et al. 1990). Because of its proclivity for deeper waters, it is likely to occur in the study area, at least in small numbers, possibly at any time of year.

The **killer whale** in the western North Atlantic may form a single, wide-ranging stock, but its status is virtually unknown (NMFS 2002b). The Northwest Atlantic population of killer whale is listed as data deficient by COSEWIC (2003a). It is seldom reported on the Scotian Shelf (Breeze et al. 2002), and was not detected in aerial surveys (Palka 2001) there or in the Gulf of St. Lawrence (Kingsley and Reeves 1998). Nevertheless, because it is very wide-ranging, it is almost certain to occur in the Laurentian Subbasin area, if only as a very rare transient.

The **long-finned pilot whale** is widespread in the western North Atlantic, where there is an estimated summer 1995 population of 9,776 (CV 0.55) from the Gulf of St. Lawrence south to Virginia (NMFS 2002b). Although not on endangered species lists of Canada or the US, human-caused mortality in the western North Atlantic population is rated as considerable relative to PBR, and it is designated a strategic stock by NMFS (2002b). It is thought to be widespread on the Scotian Shelf and further offshore throughout the year (Breeze et al. 2002), but is probably most common at and beyond the shelf break, as it is off the northeastern United States. (Payne and Heinemann 1993). Although there appear to be no published records of pilot whales occurring in the Laurentian Subbasin, its relative abundance in aerial surveys of both the Scotian Shelf and Gulf of St. Lawrence (Table 3.13) suggests that it may be equally concentrated in the Laurentian Subbasin area, both as a transient and resident and predominately in the deeper parts.

The **white-beaked dolphin** ranges widely in northern seas, with early 1980s population estimates of 3,486 (CV 0.22) for the Labrador Shelf, 5,500 (no CV estimated) for eastern Newfoundland and southeast Labrador (Ailing and Whitehead 1987), and only 573 (CV 0.69) between Cape Hatteras and Nova Scotia (NMFS 2002b). There is some indication of temporal switching between shelf and slope areas of the northeastern United States (NMFS 2002b). Although there were few records from the Scotian Shelf, it was rated as "probably fairly common" there by Breeze et al. (2002). However, the species was not identified in aerial surveys on the shelf, and was relatively scarce in aerial surveys of the Gulf of St. Lawrence (Table 3.13). Nevertheless, its regularity off eastern Newfoundland strongly suggests that it occurs in the Laurentian Subbasin (throughout) at any time of year.

The **white-sided dolphin** is as wide-ranging as the previous species, but commonly extends further south along the US East Coast, where it is categorized as a "nearshore species" (Hamazaki 2002). Recent population estimates include 51,640 (CV 0.43) between Georges Bank to the entrance of the Gulf of St. Lawrence (NMFS 2002b) and 11,740 (CV 0.47) in the Gulf of St. Lawrence (Kingsley and Reeves (1998). Because estimated human-caused mortality is low relative to population size, it is not rated as a "strategic stock" by NMFS (2002b). A hiatus in summer sightings of the Atlantic coast of Nova Scotia has been taken as an indication of a separation of Gulf of Maine and Gulf of St. Lawrence stocks (NMFS 2002b). It is, however, mapped as of "probable regular occurrence" throughout the Scotian Shelf by Breeze et al. (2002), and certainly occurs there in summer in deeper waters (Gowans and Whitehead 1995). As it was the most common species in aerial surveys of the Scotian Shelf, and outnumbered only by the more strictly coastal harbour porpoise in surveys of the Gulf of St. Lawrence (Table 3.13), it could be the most common cetacean species in the Laurentian Subbasin, possibly with spring and fall peaks involving migration of the putative Gulf of St. Lawrence stock.

Although the **short-beaked common dolphin** is thought to have a "best estimate" population size of 30,768 (CV 0.32) between Maryland and the Gulf of St. Lawrence, the level of fishery-related mortality mandates its status as a "strategic stock" (NMFS 2002b). They are generally found in deeper, slope waters off northeastern United States (NMFS 2002b), but migration onto the Scotian Shelf (Gowans and

Whitehead 1995) and eastern Newfoundland (Sergeant et al. 1970) occurs with summer warming. Although they were not detected in aerial surveys of the Gulf of St. Lawrence, one of the two groups observed in surveys of the eastern Scotian Shelf was actually in the northwestern part of the Laurentian Subbasin (Palka 2001). They are therefore certain to occur, at least in small numbers, in both shelf and channel areas of the Subbasin during summer.

A "western North Atlantic offshore stock" of the **bottlenose dolphin** frequents deep, offshore waters as far north as Atlantic Canada in summer, with a "best estimate" population size of 30,633 (CV 0.25), and is not rated as a "strategic stock" (NMFS 2002b). It is known to occur in The Gully (Gowans and Whitehead 1995) and one group was detected in aerial surveys on the eastern Scotian Shelf (Palka 2001). Although it could occur in the Laurentian Subbasin area in summer (especially in the channel), it is unlikely to do so frequently or in large numbers.

Striped dolphins form a western North Atlantic stock with a "best estimate" population size of 61,546 (CV 0.40) that is not considered a "strategic stock" (NMFS 2002b). They are characteristic of warm-temperate areas of the shelf of northeastern United States, but have been found as far north as the Grand Banks (Lens 1997). Although considered uncommon in Atlantic Canada (Baird *et al.* 1997), they have been found in some numbers in The Gully area (Gowans and Whitehead 1995), and are stated by Breeze et al. (2002) to be found in Nova Scotian waters when water temperatures exceed 15°C, although they have occurred as winter strandings on Sable Island (Lucas and Hooker 2000). However, They were not detected in summer aerial surveys of the Shelf or the Gulf (Table 3.13). This species could occur, perhaps only occasionally and in small numbers, during the summer months in the Laurentian Subbasin area.

The **harbour porpoise** is thought to form four genetically distinct (mitochondrial DNA) resident stocks in the western North Atlantic: Gulf of Maine and Bay of Fundy; Gulf of St. Lawrence; Newfoundland; and Greenland (NMFS 2002b). The "best estimate" of the size of the Gulf of Maine and Bay of Fundy stock is 89,700 (CV 0.22), and it is rated as a "strategic stock" by NMFS (2002b). There is also a possibility of a separate population along the Atlantic coast of Nova Scotia (Reeves 1999, cited in Breeze et al. 2002). In all these areas, it is found almost entirely in coastal waters (see also Hamazaki 2002). In aerial surveys of the Scotian Shelf, it was detected only in the extreme southeast (Palka 2001), although it is known offshore from strandings on Sable Island (Lucas and Hooker 2000). It was the most common cetacean detected in surveys of the Gulf (Table 3.13). In May 2003, the Northwest Atlantic population of the harbour porpoise was downlisted from threatened to being of special concern by COSEWIC (2003a). Given the existence of stocks in the Gulf and around Newfoundland, it certainly occurs in the Laurentian Subbasin area (especially on the flanking shelves), but is not likely to be frequent or common there.

A number of other cetaceans are known to have occurred only very rarely in Atlantic Canada (see Breeze et al. 2002 for a brief summary). None has been given endangered status by COSEWIC (2003a) or NMFS (2002a). Because they are widespread but rare throughout their ranges, or are regular only in regions remote from the study area, they are not considered here.

3.2.5.2 Seals

Four species of phocid seals are known or expected to occur in the Laurentian Subbasin: grey seal, harp seal, harbour seal and hooded seal. Only the harbour seal is rated by COSEWIC (2003a), and only as "data deficient". None are on the US endangered species list (NMFS 2002a).

The **grey seal** is believed to be continuing to increase from a population of 173,500 in 1996 (Hammill and Stenson 2000). They now breed on St. Pierre and Miquelon (DFO – Newfoundland, unpublished information). Exchanges between seals frequenting Sable Island and the Gulf of St. Lawrence are well documented (Stobo et al. 1990), and some of these presumably move through the Laurentian Subbasin. Beck (2002) monitored foraging grey seals equipped with satellite tags on Sable Island from October to January in areas from Georges Bank to the Gulf of St. Lawrence. Of 58 seals tagged, only four were detected in the eastern Scotian Shelf and/or the St. Pierre Bank. Movements of satellite-tagged animals of the Gulf of St. Lawrence population have not been as fully examined in this way. The only published information (Goulet et al. 1999) concerns two females captured and satellite-tagged in the Gulf that turned up on Sable Island during the next breeding season (not necessarily via the Laurentian Subbasin). However, grey seals summering on Miquelon have been later sighted back on Sable Island (DFO – Newfoundland, unpublished information), so these residents and migrants are found in or near the Laurentian Subbasin. In summary, an unknown, but probably relatively small, fraction of the Northwest Atlantic grey seal population likely forages in or moves through the Laurentian Subbasin. Nevertheless, it is likely to be the most common seal within that area.

The population status of the **harbour seal** in Atlantic Canada is much less certain, but was estimated as approximately 32,000 in 1996 (Hammill and Stenson 2000). It frequents the entire coast of Nova Scotia and much of the Gulf of St. Lawrence, but is less common along southern Newfoundland. It is regular in inshore waters, and moults and breeds on Miquelon (May to September), but may be ill-adapted to breeding on exposed, offshore sites like Sable Island (Boulva and McLaren 1979), from which it appears to be disappearing as a result of shark predation (Lucas and Stobo 2000). Accordingly, it is likely to occur only in small numbers in the Laurentian Subbasin area.

The **harp seal** is subject to a commercial hunt (some 325,000 in 2002, mostly young of the year, not whitecoats), and now has a possibly record population size (approximately 5.2 million in 1999 (McLaren et al. 2001)). It produces pups abundantly off southern Labrador and eastern Newfoundland, and in smaller numbers (depending on ice conditions) in the Gulf of St. Lawrence, which it enters and largely leaves via the Strait of Belle Isle (Sergeant 1991). Harp seals are regularly caught in lumpfish nets in NAFO Subdivision 3Ps (south coast of Newfoundland) according to Walsh et al. (2000, cited in McLaren et al. 2001). Therefore, it appears certain that some harp seals would occur seasonally in the Laurentian Subbasin, perhaps most often associated with ice drift out of the Gulf.

The **hooded seal** also breeds on the heavier pack ice off southern Labrador and northeastern Newfoundland and, to a lesser extent, in the Gulf of St. Lawrence. The Canadian population was estimated in 1990 to 1991 as 470,000 (Hammill and Stenson 2000), from which a hunt quota of 10,000 in recent years has generally not been taken. Although a new population estimate is needed, there is indirect evidence that the population has increased since 1991, and the population is not considered to be of conservation concern (McLaren et al. 2001). Although it is assumed, like the harp seal, to enter and exit the Gulf largely via the Strait of Belle Isle, the extent of any late-winter out-migration via the Laurentian Subbasin is uncertain. In recent years, more individuals have wandered to the Scotia Shelf and beyond. Furthermore, recent studies (G. Stenson, pers. comm., cited in McLaren et al. 2001) indicate that they forage more frequently than had been supposed in deeper waters of the north slope of the Laurentian Channel, Flemish Cap and southern Grand Banks, and it is possible that the species could be attracted, in fall and spring, to the slopes and deep waters of the Laurentian Subbasin.

Occasional visits by the Arctic-sub-Arctic **ringed seal**, which has bred along the Quebec North Shore, and **bearded seal**, and very rarely by the **walrus**, can be ignored in the present context.

The information provided in the previous section regarding the likely occurrence, timing and habitats of marine mammals in the Laurentian Subbasin is summarized in Table 3.14. Based on the existing, available information, only broad categorizations can be made, and the table is best taken as a series of general predictions regarding the study area. Of particular interest are those species designated under endangered species legislation in Canada, the United States, or both. As indicated in the table, the status of a number of these species is uncertain in the study area.

Table 3.14 Summary of Likely Marine Mammal Presence in the Laurentian Subbasin

Species	Occurrence	Season	Habitat	Species at Risk (Canada and/or US Designations)
Northern Right Whale	Infrequent, rare	Summer	Mostly channel	✓
Minke Whale	Regular, common	Spring, summer, fall	Mostly banks	
Fin Whale	Regular, uncommon	Spring, Summer, Fall	Throughout	✓
Blue Whale	Regular, uncommon	All year, mostly spring, fall	Mostly channel	✓
Sei Whale	Regular, uncommon	Summer	Mostly channel	✓
Humpback Whale	Regular, uncommon	Spring, summer, fall	Mostly banks	✓
Sperm Whale	Regular, uncommon	All year, mostly summer	Throughout	✓
Beluga Whale	Infrequent, very rare	All year?	Throughout	✓
Northern Bottlenose Whale	Infrequent, rare?	All year?	Channel	✓
Sowerby's Beaked Whale	Infrequent, very rare	All year?	Channel	✓
Killer Whale	Almost never, very rare	All year	Throughout?	✓
Long-finned Pilot Whale	Regular, common	All year?	Throughout	
White-beaked Dolphin	Regular, common?	All year?	Throughout	
Atlantic White-sided Dolphin	Regular, common	All year, mostly spring, fall	Mostly channel	
Short-beaked Common Dolphin	Irregular, uncommon	Summer	Throughout	
Bottlenose Dolphin	Irregular, rare	Summer	Mostly channel	
Striped Dolphin	Irregular, uncommon	Summer	Mostly banks	
Harbour Porpoise	Regular, uncommon?	All year?	Mostly banks, inshore	✓
Grey Seal	Regular, common	Mostly summer	Throughout	
Harbour Seal	Regular, uncommon	All year	Mostly banks, inshore	✓
Harp Seal	Regular, uncommon	Late winter, early spring	Throughout	
Hooded Seal	Regular, uncommon?	Especially late winter?	Mostly channel?	

Note: ? indicates particularly uncertain status.

3.2.6 Sea Turtles

Two species of sea turtles are known as regular summer migrants to Atlantic Canada, the leatherback turtle and Atlantic loggerhead turtle. A third, Kemp's Ridley turtle, is rare and has only occurred south of the study area. General information on the distribution and biology of sea turtles that occur in Atlantic Canada is available in Breeze et al. (2002), the NMFS web site (NMFS 2002c), and from the Nova Scotia Sea Turtle Working Group (n.d.). Major threats to sea turtles are exploitation as food, especially in their breeding ranges, fisheries bycatches, and to a lesser extent collisions with boats.

The world-wide population of **leatherback turtles** has recently been estimated to range between 26,000 and 43,000 animals (Dutton et al. 1999). The species is listed as endangered in the United States (NMFS 2002c) and Canada (COSEWIC 2003a). The species is listed as a Schedule 1, Part 2 (Endangered) species under the Canadian *Species at Risk Act*. Doherty (2002) demonstrated from bycatch rates off the eastern United States and Grand Banks, corrected for effort, that the leatherback population is

continuing to decrease. They are regularly sighted in waters as far north as off eastern Newfoundland from June to October, with peak abundance in August (Husky Oil 2000). Breeze et al. (2002) state that they are regularly observed on the Scotian Shelf, but plot bycatch records exclusively from off-shelf areas, including one within the Laurentian Subbasin at the mouth of the Laurentian Channel. At least three individuals have been satellite-tagged near or in the Subbasin (Nova Scotia Sea Turtle Working Group n.d.) and there have been numerous sightings along the northeast flank of the Scotian Shelf (M. James, pers. comm.). Accordingly, the endangered population of leatherback turtles is a potentially vulnerable species that is known to occur within the Laurentian Subbasin study area in the summer months.

The **loggerhead turtle** is the most common sea turtle species in North American waters, where its population has most recently been estimated to number between 9,000 and 50,000 adults (Ernst et al. 1994). The species is listed as threatened under the United States *Endangered Species Act* (NMFS 2002c), but COSEWIC (2003a) has not conferred status on it. Doherty (2002), from bycatch rates from the eastern United States to the Grand Banks (corrected for effort), concluded that the loggerhead turtle population in that region is increasing, although elsewhere populations are in decline (NMFS 2002c). It has not been observed as frequently as the leatherback on the Scotian Shelf, and almost all bycatch in Atlantic Canada has been well off the Shelf or southeast of the Grand Banks (plotted as "hardshell turtles" by Breeze et al. 2002). Its summer occurrence within the Laurentian Subbasin is predicted to be very rare.

The information provided in the previous section regarding the likely occurrence, timing and habitats of sea turtles in the Laurentian Subbasin is summarized in Table 3.15.

Table 3.15 Summary of Likely Sea Turtle Presence in the Laurentian Subbasin

Species	Occurrence	Season	Habitat	Species at Risk (Canada and/or US Designations)
Leatherback Turtle	Regular, uncommon	Summer	Channel	✓
Loggerhead Turtle	Regular, rare?	Summer	Channel	✓
Kemp's Ridley Turtle	Almost never, very rare	Summer	Channel	✓
Note: ? indicates particularly uncertain status.				

3.2.7 Special Areas

At present, there are no designated marine protected areas within the study area (D. Fenton, pers. comm.).

The Stone Fence is an area located along the southwestern side of the Laurentian Channel, along the shelf break of Banquereau Bank (Figure 3.8), extending a distance of approximately 100 km. This feature is recognized as providing habitat for a variety of fish species, and is a favoured fishing area with a wide variety of fish caught (R. O'Boyle, pers. comm.). As indicated in the fisheries distribution maps in Appendix C, the area sees considerable fishing activity for a wide variety of species, including cod, redfish, halibut, American plaice, flounder, skate, swordfish, shark, cusk and white hake in recent years. As discussed in Section 3.2.2.2, deep-sea corals are also known to occur at the site. Because of the newly discovered *Lophelia* reef, DFO has recognized this as an important area. The Stone Fence is recognized as an area of special ecological and social importance in the general region.

3.3 Socio-economic Environment

3.3.1 The Fishery

The fishery has played an important role in the history of Atlantic Canada, and remains an integral component of the economy of the region.

3.3.1.1 Regional Management and Data Sources

The Northwest Atlantic is divided into a series of NAFO Divisions and Unit Areas (Figures 3.9 and 3.10). Although fisheries management and harvesting activities extend across NAFO boundaries, these regions are widely used to describe fishing activity. For the purposes of this assessment, fisheries in NAFO Divisions 3Ps, 4Vn and 4Vs are described (Figure 3.9), as are fisheries in the NAFO Unit Areas, which overlap the Laurentian Subbasin area, (i.e., Unit Areas 3Psf, 3Psg, 3Psh, 4Vsb, 4Vsc; Figure 3.10).

Both NAFO and DFO manage fisheries in the area. DFO assumes primary responsibility for stocks that do not straddle the 200-mile limit or that are sedentary. NAFO assumes primary responsibility for most stocks outside the 200-mile limit and straddling stocks, with advice from DFO. Large pelagic fish species are managed by the International Commission for the Conservation of Atlantic Tunas (ICATT). DFO Newfoundland manages fisheries in 3L, 3O and 3Ps; DFO Maritimes manages fisheries in 4V and 4W. DFO also manages Aboriginal fisheries in the areas, exploratory fisheries and fisheries in the St. Pierre and Miquelon Exclusive Economic Zone (EEZ). Quotas in and around this EEZ are granted to France under a treaty signed in December 1994 (D. Bryand, pers. comm.).

Figure 3.8 The Stone Fence

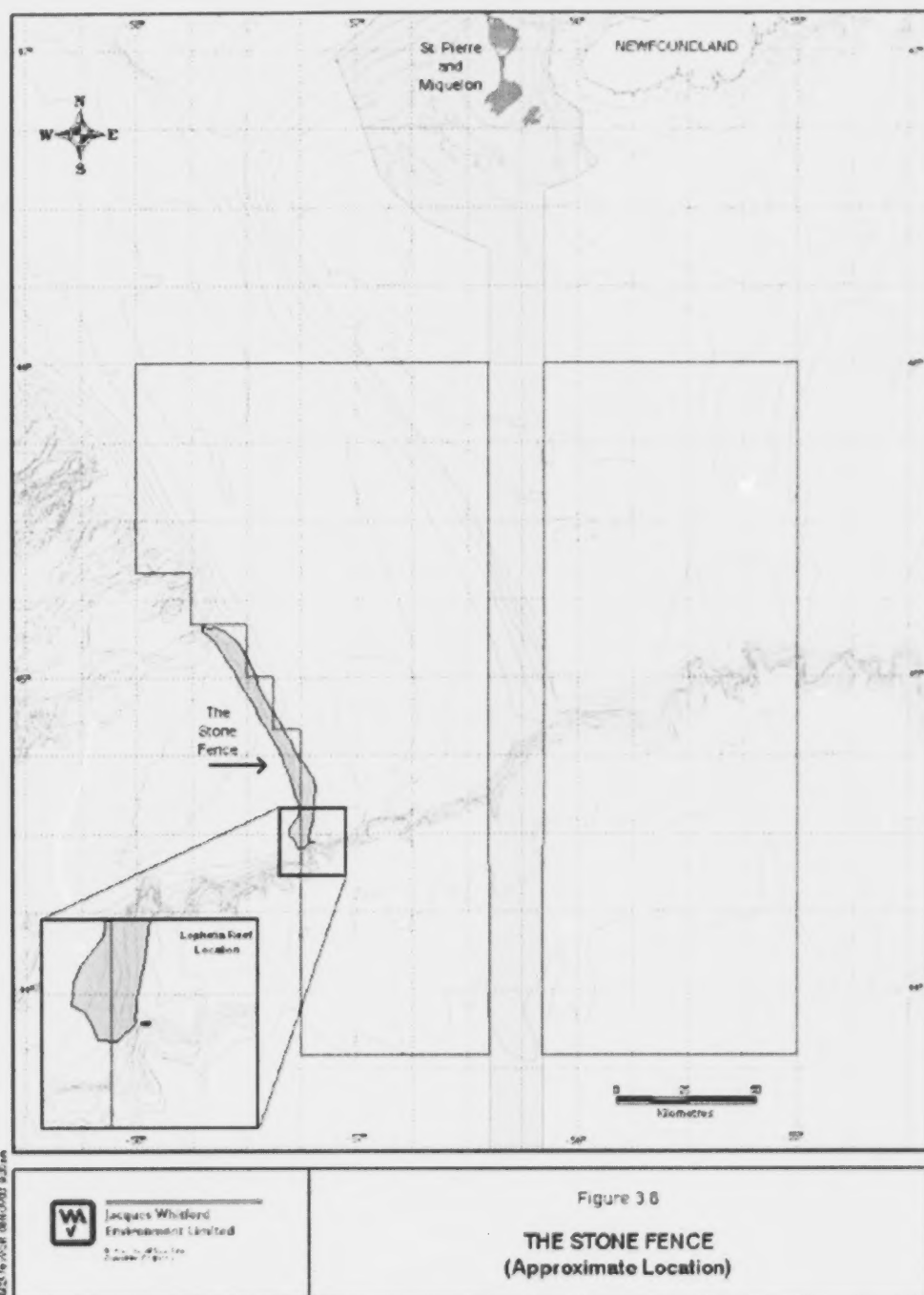
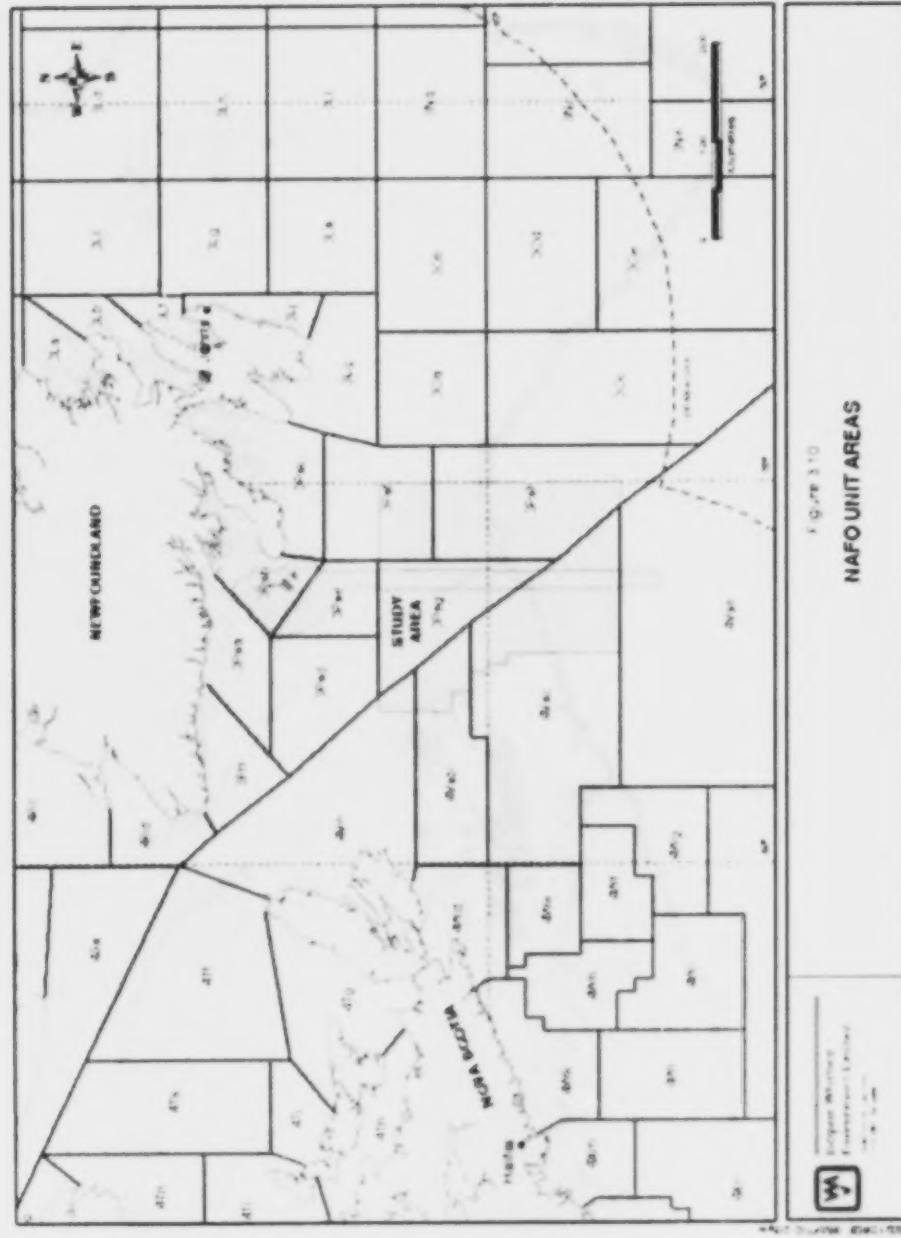


Figure 3.10 NAFO Unit Areas



The primary information sources used to describe the fishery are Canadian fisheries catch data from 1995 to 2001 obtained from DFO, and St. Pierre and Miquelon catches, also from 1995 to 2001, obtained from NAFO. Canadian cash landings for 2001 for NAFO Divisions 4Vn and 4Vs are presently unavailable. Therefore, cash landings for 2000 are used in this report as the most recent cash statistics for these Divisions. Catch by weight is reported for 2001 for these Divisions; catch by weight for 2000 is also provided for comparison with 2000 cash landings. Cash landings are unavailable for St. Pierre and Miquelon catches. Where geospatial information is available, the location of some key fisheries relative to the study area and potential traffic routes is presented. Typically, geospatial information is available for Canadian offshore fisheries but is limited for inshore fisheries (see Tables 1 and 2, Appendix C).

3.3.1.2 Fisheries Overview

NAFO Division 3Ps

Canadian commercial catches in NAFO Division 3Ps from 1995 to 2001 averaged 33,479 tonnes per year, ranging from a low of 13,946 tonnes in 1995 to a high of 48,162 tonnes in 1999 (see Appendix C for detailed catch data). Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included lumpfish, snow crab, lobster, Iceland and sea scallop, redfish, skate, herring and cod. Of these, redfish and snow crab have consistently constituted an important portion of the overall catch by weight, although cod has increased since 1997.

Of the 35,912 tonnes harvested in 3Ps in 2001, cod accounted for 38.2 percent of the catch, snow crab comprised 21.9 percent, and redfish comprised 11.5 percent. During that year, the landed value of fish harvested by Canadian vessels in 3Ps was approximately \$67 million. Snow crab accounted for 45.4 percent of this amount, cod accounted for 27.3 percent and lobster accounted for 12.9 percent. The redfish fishery, being less lucrative, accounted for only 3.1 percent of the cash landings for the 3Ps fishery in 2001. Conversely, although the lobster fishery contributed measurably to cash landings, this fishery accounted for only 2 percent of catch by weight in 2001.

The fishery in 3Ps is predominantly a fixed gear (pot or fixed gill net) fishery and conducted mostly by vessels under 45 ft in length, although vessels greater than 65 ft in length operate further offshore. A total of 7,804 fishing sets were made in Division 3Ps in 2001. Forty-nine percent of sets targeted cod, 19.6 percent targeted crab and 10.3 percent targeted redfish. Vessels registered in Newfoundland accounted for 92.1 percent of the fishing activity and vessels registered in Nova Scotia accounted for the remainder.

In addition to the above, there are now 119 exploratory or supplementary permits for crab in 3Ps south of 46°30' (T. Curran, pers. comm.). Also, the Newfoundland and Labrador Department of Fisheries and

Aquaculture plans to promote the development of an experimental sea cucumber fishery in and around the study area (P. Shea, pers. comm.).

For St. Pierre and Miquelon, catches in NAFO Division 3Ps averaged 3,342 tonnes from 1995 to 2001, ranging from 309 tonnes in 1995 to 6,430 tonnes in 2000 (Appendix C). The composition of the St. Pierre and Miquelon fishery in this Division is similar to, although somewhat less diversified than, the Canadian fisheries. Species that accounted for greater than 5 percent of the overall catch since 1995 have included lumpfish, cod, snow crab, porbeagle shark, Iceland scallop and redfish. Of the 3,802 tonnes of fish harvested by St. Pierre and Miquelon fishers in 2001, cod comprised 61.8 percent and snow crab comprised 13.1 percent of the catch. Conversely, lumpfish accounted for 73.1 percent of the catch by weight in 1995. St. Pierre and Miquelon fishers have not fished in other NAFO Divisions in the study area since 1995.

NAFO Division 4Vn

Canadian commercial catches in NAFO Division 4Vn averaged 9,927 tonnes from 1995 to 2001, ranging from 7,320 tonnes in 2001 to 14,119 tonnes in 1995. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included lobster, mackerel, redfish, herring, snow crab, American plaice and shrimp.

Snow crab and lobster have consistently dominated cash landings. Of the 7,320 tonnes harvested in 4Vn in 2001, lobster made up 23.8 percent of the catch, crab made up 20.7 percent, herring 20.8 percent, redfish 10.8 percent and shrimp accounted for 7 percent. In 2000, lobster comprised approximately 19 percent of the 7,451 tonnes landed, redfish 18.6 percent, snow crab 18.3 percent, herring 12.6 percent, and mackerel accounted for 9.7 percent. The landed value of fish harvested by Canadian vessels in 4Vn in 2000 was roughly \$28 million. Lobster accounted for 60.4 percent of this total and snow crab accounted for 26.3 percent.

The Canadian fishery in 4Vn is predominantly a fixed gear (pot) fishery and mostly conducted by vessels under 45 ft in length. Again, vessels greater than 45 ft would operate further offshore. A total of 1,984 fishing sets were made in Division 4Vn in 2001. Forty-one percent of these sets targeted the inshore lobster fishery, while 17.6 percent targeted snow crab. The remainder targeted a variety of species including cod, redfish, herring and rock crab. Nova Scotia fishers accounted for 97.7 percent of the fishing activity, Quebec fishers accounted for 1.7 percent, and New Brunswick and Newfoundland accounted for the remainder.

Exploratory fisheries have also occurred in the general region, including, for example, exploratory shrimp trawling activity in recent years. There reportedly continues to be considerable interest in shrimp in the general area (B. Osborne, pers. comm.; P. Koeller, pers. comm.).

NAFO Division 4Vs

Canadian commercial catches in NAFO Division 4Vs averaged 28,201 tonnes from 1995 to 2001, ranging from 22,339 tonnes in 1995 to 35,383 tonnes in 1999. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings included shrimp, redfish, skate, swordfish, Arctic surf clams and snow crab.

Arctic surf clams have dominated the fishery in this division since 1995. Of the 23,727 tonnes harvested in 4Vs in 2001, this species accounted for 48.2 percent of the catch, redfish accounted for 16.6 percent, snow crab accounted for 15.6 percent and shrimp accounted for 5.2 percent. In 2000, Arctic surf clams made up 64.2 percent of the 30,038 tonnes landed, snow crab 11.6 percent, and shrimp comprised 6 percent. During that year, the landed value of fish harvested by Canadian vessels in 4Vs was roughly \$44 million. Arctic surf clams accounted for 35.8 percent of this total, snow crab 41.2 percent, and shrimp 8.7 percent.

Both mobile (dredge) and fixed (pot) gear and frequently used in 4Vs. These two gear types constituted over 50 percent of gear types used in this Division in 2001. A total of 3,996 fishing sets were made in Division 4Vs in 2001. Thirty-one percent of these sets targeted crab and 22.2 percent targeted Arctic surf clams. The remainder focussed mostly on redfish, Atlantic halibut, sea scallop and shrimp. Vessels registered in Nova Scotia accounted for 71.3 percent of this fishing activity in 2001 and vessels registered in Newfoundland accounted for the remainder.

3.3.1.3 Fisheries in NAFO Unit Areas that Overlap the Study Area

NAFO Unit Area 3Psf

Canadian commercial catches in NAFO Unit Area 3Psf averaged 4,311 tonnes from 1995 to 2001, ranging from 1,427 in 1995 to 6,991 tonnes in 1999. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included snow crab, Iceland scallops, sea scallops, cod, and porbeagle shark. Of the 5,590 tonnes harvested in 3Psf in 2001, snow crab accounted for 65 percent of catches, cod accounted for 25.1 percent and Iceland scallops accounted for 5.3 percent. During that year, the landed value of fish harvested by Canadian vessels in 3Psf was roughly \$16.4 million. Snow crab accounted for 84.6 percent of this total and cod accounted for 11.9 percent. Scallop accounted for less than 5 percent of cash by landings.

The Canadian fishery in 3Psf is predominantly a fixed gear (pot) fishery and mostly conducted by vessels under 45 ft in length. A total of 1,713 fishing sets were made in 3Psf in 2001. Sixty-five percent of these sets targeted crab and 28 percent targeted cod. Vessels registered in Newfoundland accounted for 99.3 percent of this fishing activity and vessels registered in Nova Scotia accounted for the remainder.

NAFO Unit Area 3Psg

Canadian commercial catches in NAFO Unit Area 3Psg from 1995 to 2001 averaged 2,660 tonnes per year, ranging from 367 tonnes in 1996 to 4,673 tonnes in 1999. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included skate, Atlantic halibut, porbeagle shark, sea scallops, Iceland scallops, Greenland halibut, redfish, and cod. Of the 940 tonnes harvested in 3Psg in 2001, redfish accounted for 46.8 percent, skate accounted for 15.8 percent, cod accounted for 12.8 percent and Iceland scallops for 9.5 percent. During that year, the landed value of fish harvested by Canadian vessels in 3Psg was approximately \$0.6 million. Redfish accounted for 34.4 percent of this total, cod accounted for 20.4 percent, Iceland scallops accounted for 21.2 percent, sea scallops for 8.9 percent and skate for 6.0 percent.

The Canadian fishery in 3Psg is predominantly a mobile gear (bottom trawl) fishery and is mostly conducted by vessels over 65 ft. A total of 264 fishing sets were made in 3Psg in 2001. Thirty-six percent targeted redfish, 19.3 percent targeted cod, 15.9 percent targeted skate, 13.3 percent targeted Atlantic halibut, 7.2 percent targeted Iceland scallop and 6.8 percent targeted white hake. Vessels registered in Newfoundland accounted for 67.4 percent of this total and vessels registered in Nova Scotia accounted for the remainder.

NAFO Unit Area 3Psh

Canadian commercial catches in NAFO Unit Area 3Psh from 1995 to 2001 averaged 3,966 tonnes per year, ranging from 1,298 in 1996 to 6,817 tonnes in 2000. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included cod, Atlantic halibut, Greenland halibut, skate, pollock, white hake, monkfish, porbeagle shark, haddock, witch flounder, American plaice, and redfish. Of the 5,601 tonnes harvested in 3Psh in 2001, cod accounted for 45.1 percent, skate accounted for 16.5 percent, white hake accounted for 8.1 percent, American plaice accounted for 5.9 percent, and witch flounder accounted for 5.4 percent. During that year, the landed value of fish harvested by Canadian vessels in 3Psh was roughly \$5.3 million. Cod accounted for 55.6 percent of this total, Atlantic halibut accounted for 6.8 percent, witch flounder accounted for 5.8 percent, and American plaice accounted for 5.6 percent.

The Canadian fishery in 3Psh is predominantly a mobile gear (bottom trawl) fishery and mostly conducted by vessels over 65 ft in length. A total of 1,536 fishing sets were made in 3Psh in 2001. The most common target species were cod (30.8 percent), skate (16.5 percent), witch (13.5 percent), white hake (12.7 percent), Atlantic halibut (9.1 percent), monkfish (7.2 percent) and redfish (6.1 percent). Vessels registered in Newfoundland accounted for 84.4 percent of this fishing activity and vessels registered in Nova Scotia accounted for the remainder.

NAFO Unit Area 4Vsb

Canadian commercial catches in NAFO Unit Area 4Vsb from 1995 to 2001 averaged 1,095 tonnes per year, ranging from 419 in 1995 to 2,463 tonnes in 2000. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included snow crab, shrimp, redfish, pollock, and American plaice. Of the 2,067 tonnes harvested in 4Vsb in 2001, snow crab accounted for 80.3 percent, redfish accounted for 10.5 percent, and shrimp accounted for 6.4 percent. In 2000, snow crab accounted for 84 percent of the 2,463 tonnes landed and shrimp accounted for 5 percent. During that year, the landed value of fish harvested by Canadian vessels in 3Vsb was roughly \$11 million and snow crab accounted for 95.3 percent of this total.

The Canadian fishery in 4Vsb is predominantly a fixed gear (pot) fishery and mostly conducted by vessels under 45 ft in length. A total of 683 fishing sets were made in 4Vsb in 2001. Eighty-two percent of sets targeted snow crab and 8.6 percent targeted redfish. Vessels registered in Nova Scotia accounted for 99.8 percent of this fishing activity and Newfoundland vessels accounted for the remainder.

NAFO Unit Area 4Vsc

Canadian commercial catches in NAFO Unit Area 4Vsc from 1995 to 2001 averaged 26,819 tonnes per year, ranging from 21,397 in 1995 to 34,017 tonnes in 1999. Over these years, fisheries that have accounted for greater than 5 percent of the overall catch by weight or by cash landings have included Arctic surf clams, redfish, shrimp, snow crab, Atlantic halibut, swordfish, sea scallops, and skate. Of the 21,398 tonnes harvested in 4Vsc in 2001, Arctic surf clams accounted for 53.3 percent, redfish accounted for 16.9 percent, snow crab accounted for 9.6 percent, and shrimp accounted for 5.1 percent. In 2000, Arctic surf clams made up 70 percent of the 27,532 tonnes caught, shrimp made up 6.1 percent, and snow crab made up 5.1 percent. During that year, the landed value of fish harvested by Canadian vessels in 4Vsc was roughly \$33.1 million. Arctic surf clams accounted for 48.1 percent of this total, snow crab accounted for 23.2 percent and shrimp accounted for 10.8 percent.

The Canadian fishery in 4Vsc is predominantly a mobile gear (dredge) fishery and mostly conducted by vessels under 65 ft in length. A total of 3,249 fishing sets were made in 4Vsc in 2001. The primary target species in 2001 included Arctic surf clams (27.4 percent of sets), crab (21.6 percent), redfish (15.2 percent), Atlantic halibut (9.1 percent), sea scallop (8.4 percent) and shrimp (6.4 percent). Vessels registered in Nova Scotia accounted for 64.7 percent of this fishing activity in 2001 and vessels registered in Newfoundland accounted for the remainder.

3.3.1.4 Fisheries Within the Laurentian Subbasin

An indication of the overall distribution of fisheries in the Laurentian Subbasin itself for the 1995 to 2001 period is provided in Figures 3.11 to 3.14 (based on the available, valid geospatial coordinates, see Appendix C).

As illustrated, the overall distribution of fishing activity within the study area varies according to season, with a number of general trends evident in recent years. For example:

- in winter (January to March), fishing activity in recent years has been concentrated primarily along the shelf in the southern portion of the study area, as well as to the northwest within the Laurentian Channel;
- in spring (April to June), considerable fishing has occurred along the shelf in the southeastern portion of the study area, as well as over the St. Pierre Bank and Halibut Channel and along the bank slope;
- in summer (July to September), fishing activity is relatively more dispersed throughout the region, with fishing occurring on the St. Pierre Bank and Halibut Channel, along the shelf area, and along the slopes and within the Laurentian Channel;
- in the fall period (October to December), considerable fishing activity occurs along the shelf in the southern part of the study area, as well as throughout the eastern portion of the area over the St. Pierre Bank and slope.

Information on the spatial and seasonal distribution of fishing effort for individual species is provided in Appendix C.

Information on the value of landings by species for directed fisheries within the study area from 1995 to 2001 is provided in Table 3.16.

Summary information on the distribution of fishing activity by catch value is provided in Figures 3.15 to 3.18. The figures identify cash landings averaged over 5 km² blocks (top panel) and cash landings interpolated over 10 km² blocks (bottom panel). The information presented in both cases is similar, but spatial interpolation better identifies key fishing areas whereas spatial averaging, as provided, provides a better indication of the overall distribution of the fishery.

Most fishing activity occurs in fall (Figures 3.11 through 3.18). From 1995 to 2001, fish landings in the study area in the fall totalled \$26,320,339. Landings in spring, summer and winter totaled \$17,973,701, \$15,291,615 and \$12,666,397, respectively (Table 3.16). The most active fishing months by species are illustrated in Figure 3.19. Fishing effort by species by season is illustrated in Appendix C.

Figure 3.11 Fishing Activity (January – March)

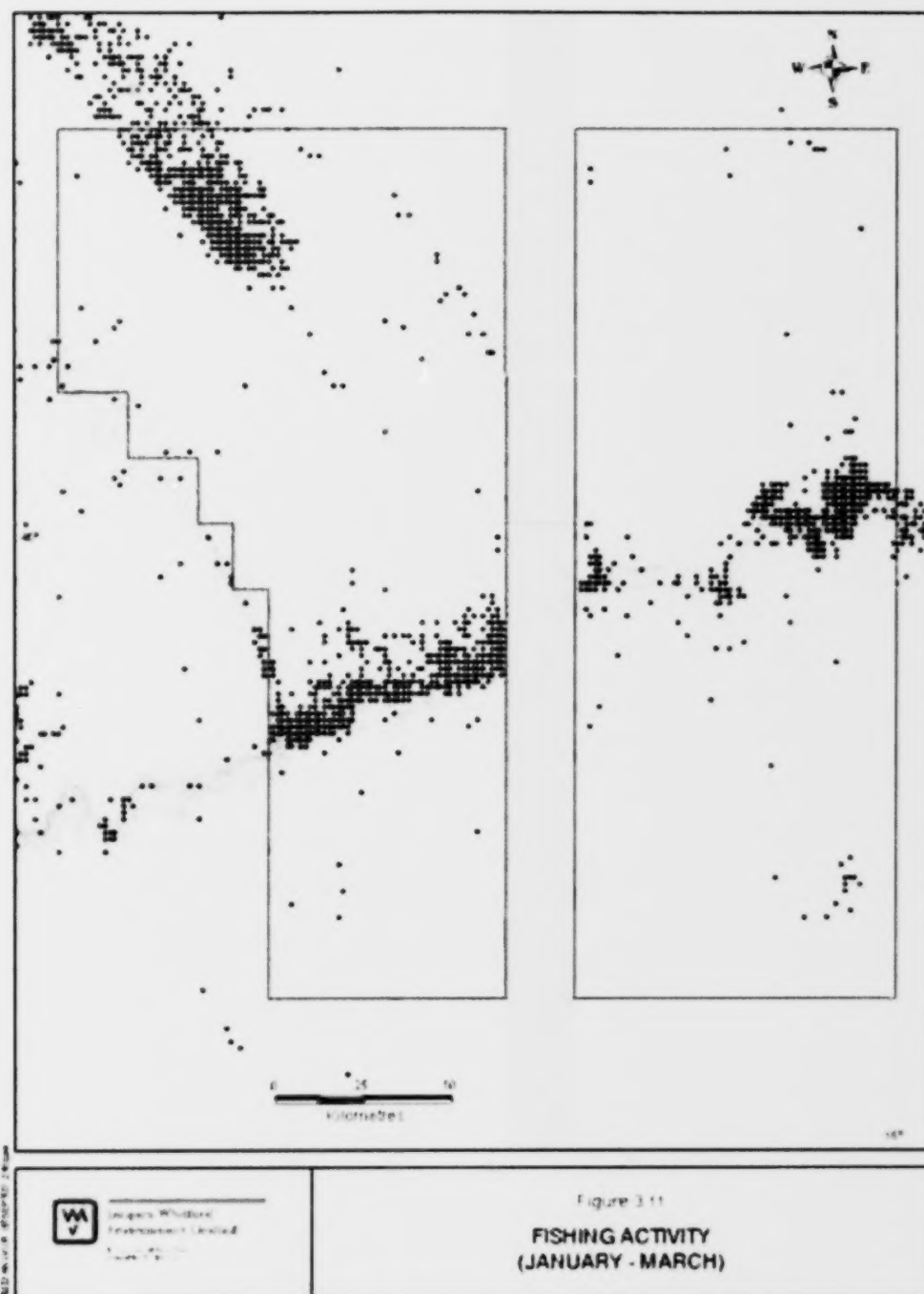


Figure 3.12 Fishing Activity (April - June)

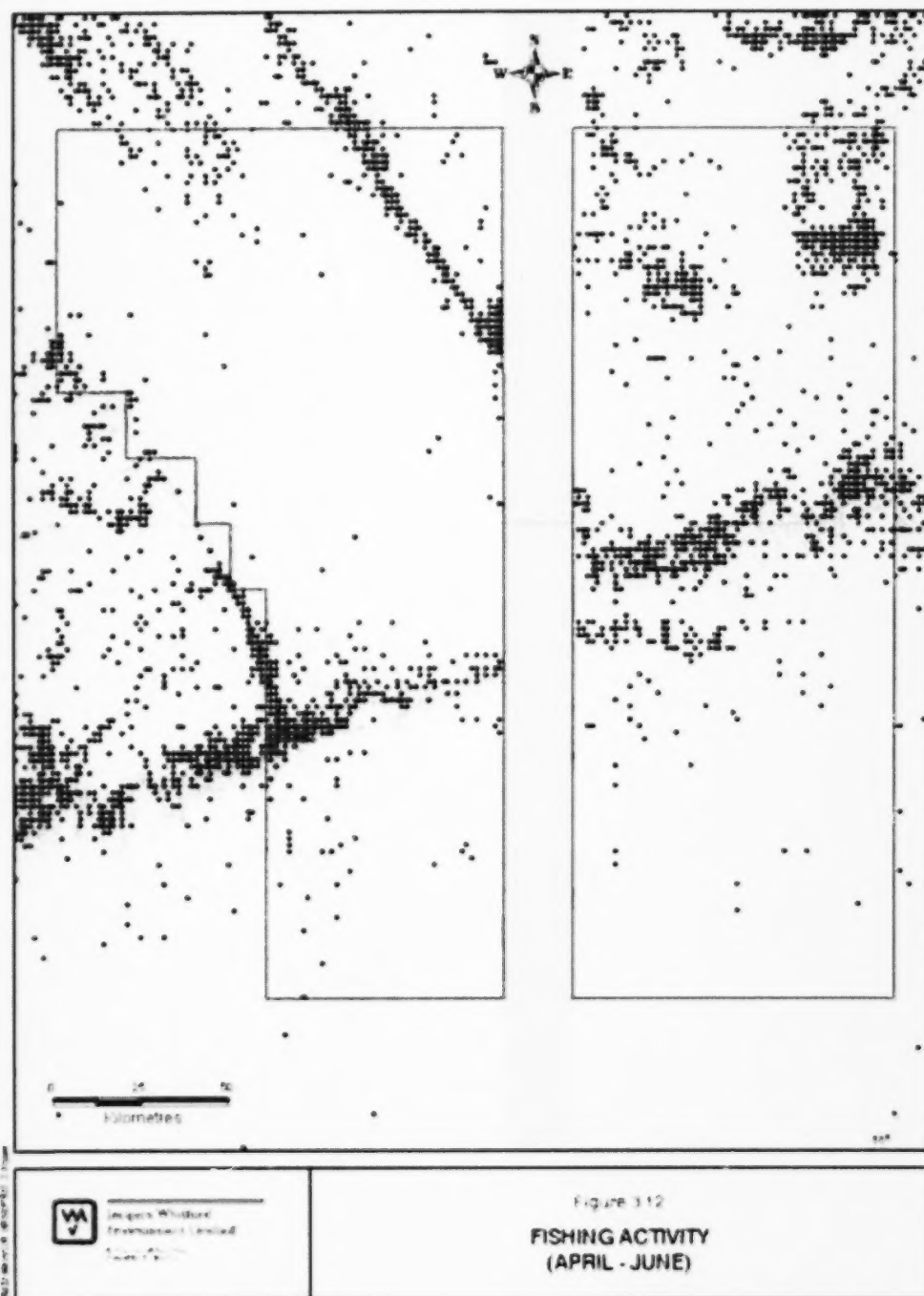


Figure 3.13 Fishing Activity (July - September)

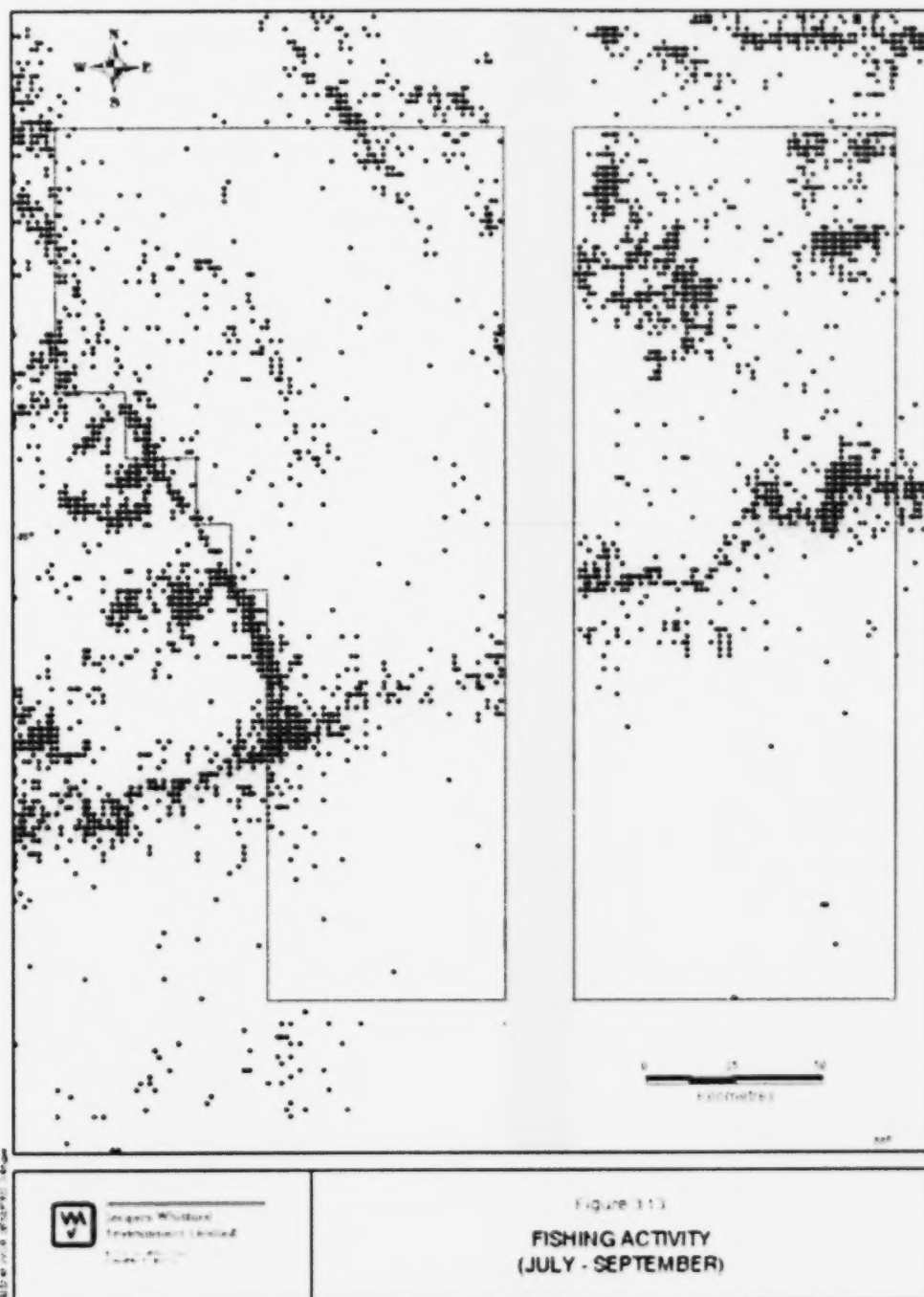


Figure 3.14 Fishing Activity (October - December)

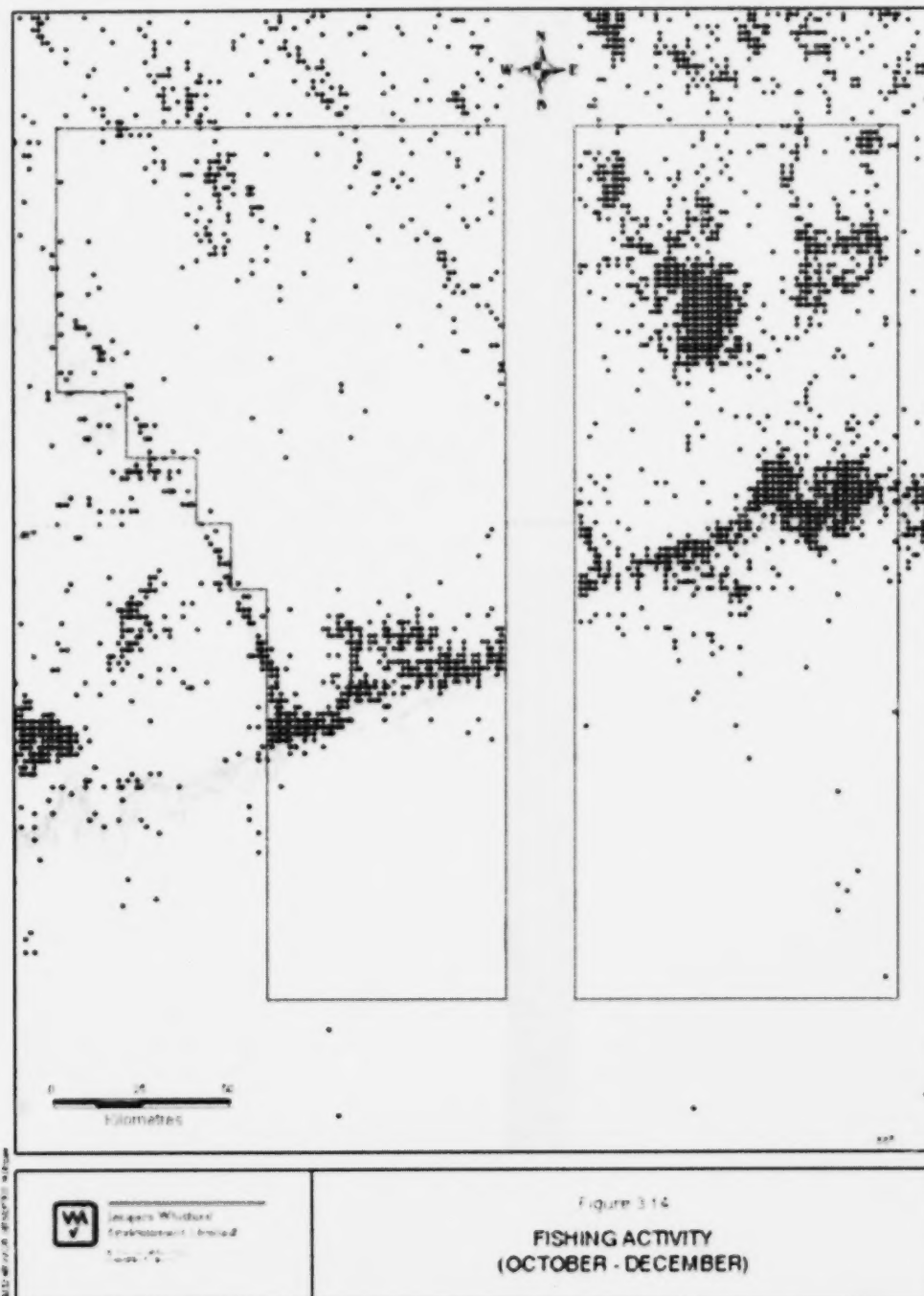


Table 3.16 Value of Landings by Species by Season in the Study Area (1995-2001)

Species	Winter (Jan – Mar)	Spring (Apr – Jun)	Summer (Jul – Sept)	Fall (Oct – Dec)	Total
Cod	\$4,023,223	\$2,240,202	\$5,068,889	\$15,083,317	\$26,415,631
Snow Crab	\$0	\$10,348,300	\$4,938,117	\$5,575,302	\$20,861,719
Redfish	\$5,378,099	\$818,797	\$572,740	\$2,343,064	\$9,112,699
Atlantic Halibut	\$3,361,846	\$1,660,398	\$325,112	\$981,562	\$6,328,919
Iceland Scallop	\$0	\$1,015,586	\$918,390	\$613,689	\$2,547,664
Skate	\$44,728	\$1,144,563	\$120,909	\$318,824	\$1,629,024
White Hake	\$398,992	\$295,903	\$503,806	\$369,342	\$1,568,043
Porbeagle Shark	\$4,802	\$699,261	\$323,814	\$514,031	\$1,541,908
Pollock	\$256,801	\$333,610	\$816,171	\$571,713	\$1,978,295
American Plaice	\$245,343	\$62,850	\$321,271	\$362,297	\$991,760
Turbot-Greenland Halibut	\$38,090	\$331,057	\$195,923	\$108,554	\$673,623
Sea Scallop	\$0	\$73,656	\$511,924	\$53,032	\$638,612
Witch Flounder	\$312,155	\$13,200	\$4,668	\$257,239	\$587,262
Swordfish	\$0	\$0	\$1,379,788	\$2,933	\$1,382,721
Haddock	\$63,211	\$55,081	\$239,574	\$193,024	\$550,889
Monkfish	\$12,926	\$199,891	\$127,152	\$34,816	\$374,785
Yellowtail Flounder	\$25,778	\$1,911	\$52,035	\$216,917	\$296,641
Shrimp	\$0	\$59,030	\$158,389	\$0	\$217,419
Arctic Surf Clam	\$0	\$95,663	\$0	\$0	\$95,663
Cusk	\$14,673	\$19,099	\$9,902	\$13,999	\$57,674
Bigeye tuna	\$0	\$0	\$12,414	\$0	\$12,414
Total	\$12,666,397	\$17,973,701	\$15,291,615	\$26,320,339	\$72,252,052

Note: The information provided in this table is for directed fisheries which have occurred within the boundaries of the study area from 1995 to 2001. Values are derived from the available geospatial data on fisheries distributions (see Appendix C, Table 1 and 2).

Based on the distribution and timing of cash landings (Table 3.16; Figures 3.15 to 3.18) and fishing effort (Appendix C), key fisheries in the study area (i.e., species that have generated seasonal landings (1995 to 2001) from the study area of \$1 million or more) include:

- redfish, cod and Atlantic halibut fisheries from January to March;
- snow crab, cod, Atlantic halibut, skate and Iceland scallop fisheries from April to June;
- cod, snow crab, swordfish and Iceland scallop fisheries from July to September; and
- cod, snow crab and redfish fisheries from October to December.

By far the most lucrative fisheries in the study area in recent years have been those for cod and snow crab. Each of these species generated cash landings of over \$20 million from 1995 to 2001. In 2001, cod landings were in the order of \$4.5 million and crab landings were \$5 million. Reported landings within the study area for Iceland scallop, redfish and Atlantic halibut (species that closely follow cod and crab in terms of cash landings), were in the order of \$1.2, \$0.6 and \$0.5 million in 2001, respectively.

Figure 3.15 Winter (January to March) Average Fishing Value

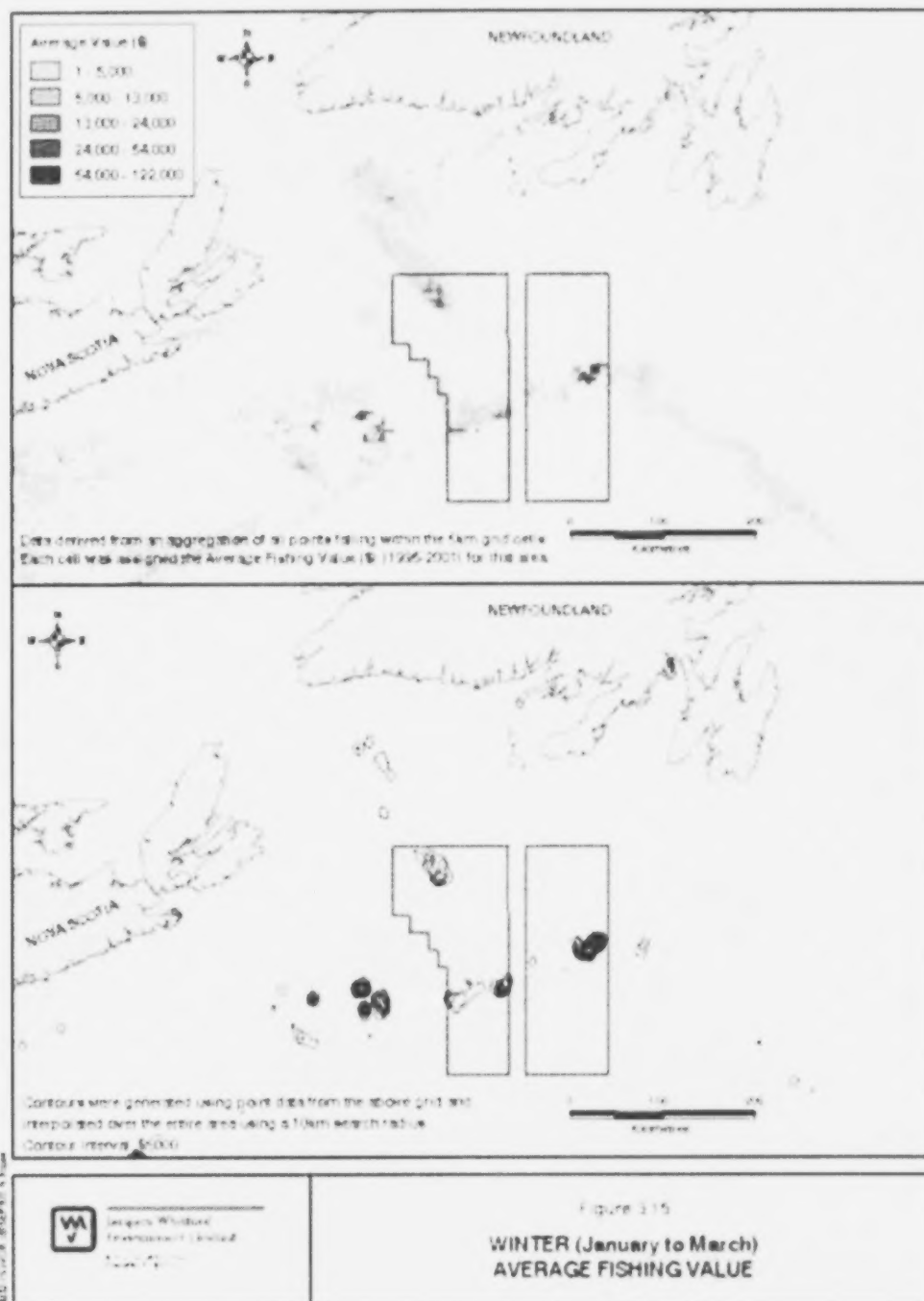


Figure 3.16 Spring (April to June) Average Fishing Value

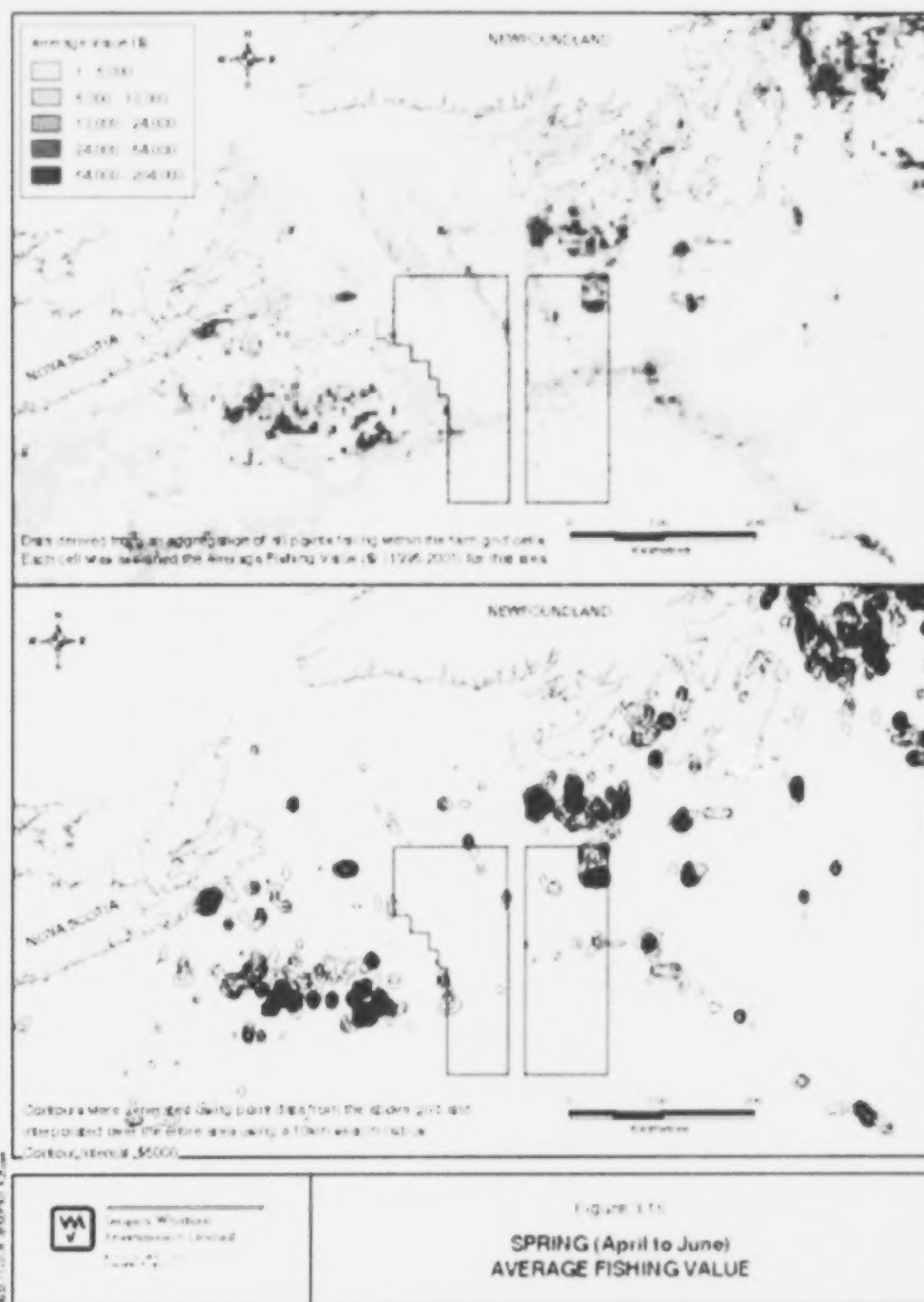


Figure 3.17 Summer (July to September) Average Fishing Value

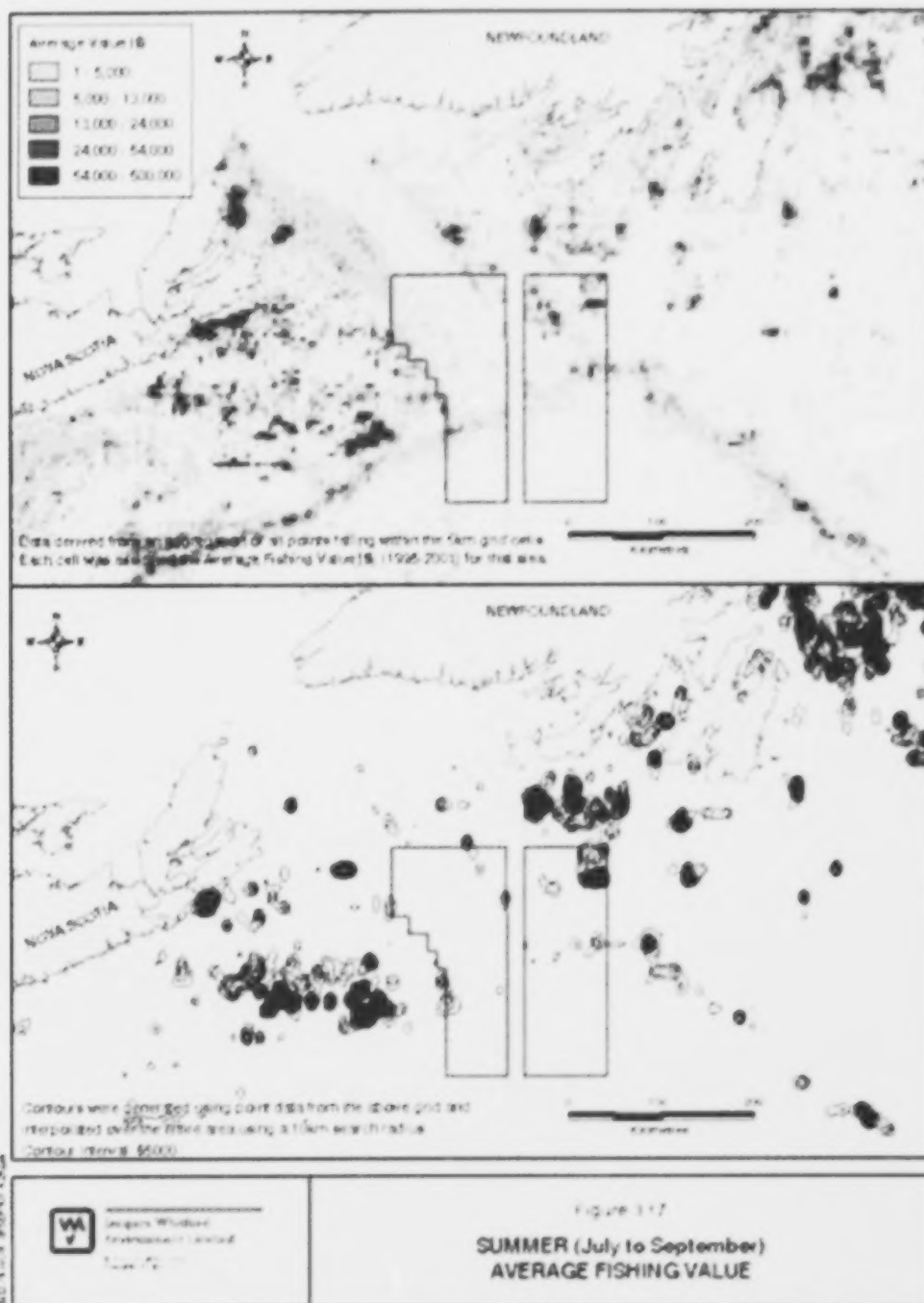


Figure 3.18 Fall (October to December) Average Fishing Value

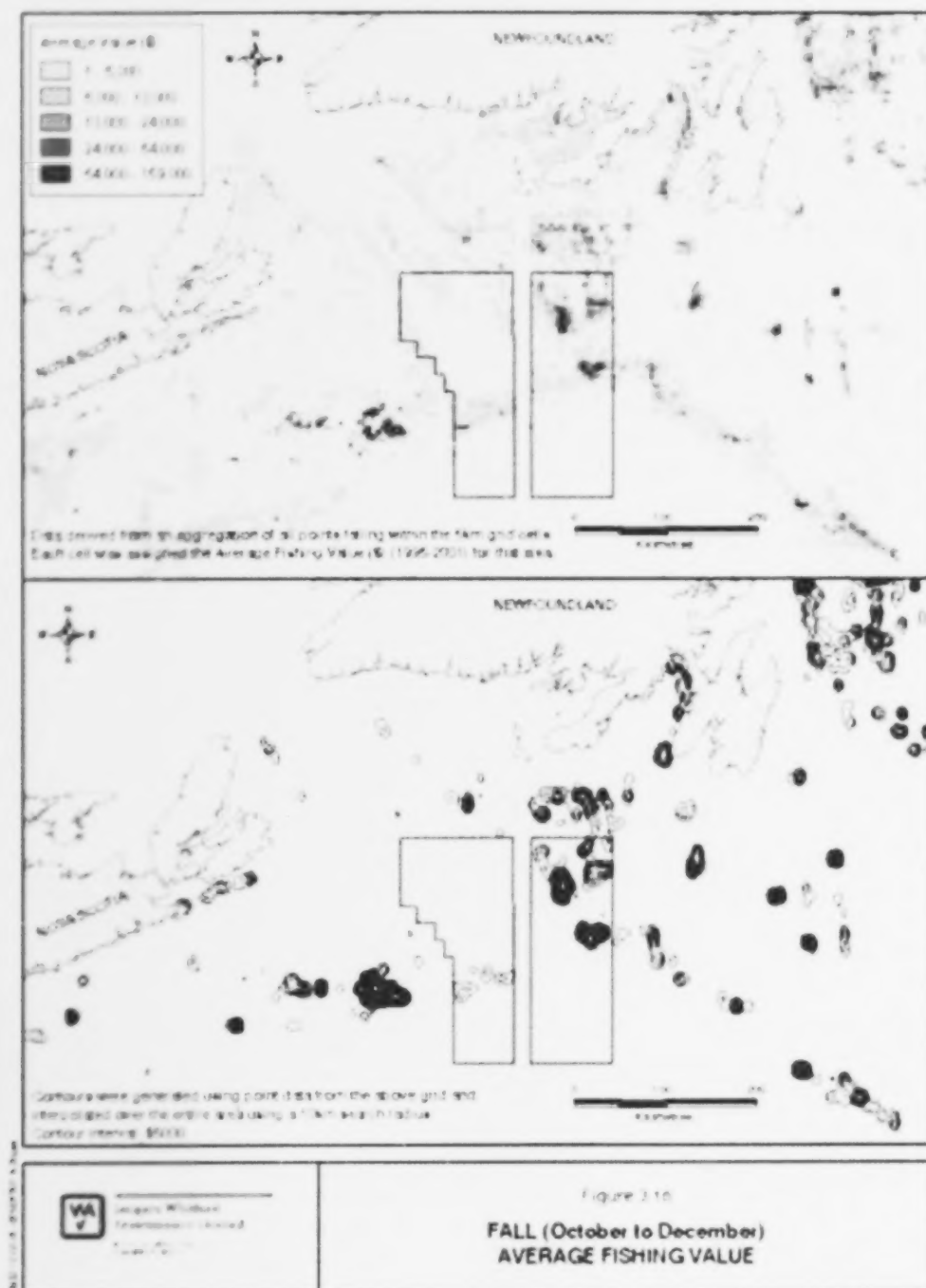


Figure 3.19 High Catch Months for Selected Species Fished in the General Region
Figure 3.19 High Catch Months for Selected Species Fished in the General Region



Source: DFO Statistical Services

Species selected are those that have generated a cumulative total of over \$60,000 in cash landings from 1995 to 2001 in NAFO Divisions 3Ps, 4V and 4Vs.

3.3.1.5 Vessel Activity

The most intensive Canadian fishing activity in the region occurs from April to December, with relatively little fishing activity from January to March. Fishing vessel density information (averaged over 2-km² square blocks) by season for both fixed and mobile fishing gear is provided in Appendix C.

The highest vessel densities for fixed gear fisheries occur from April to June on the southern edge of the St. Pierre Bank, off the Burin Peninsula and in Fortune and Placentia Bay; and from July to September around Cape Breton Island and the middle Nova Scotia Shelf. The most intensive fishing activity with mobile gear occurs from April to June off the Nova Scotia Shelf and mostly in the Banquereau area.

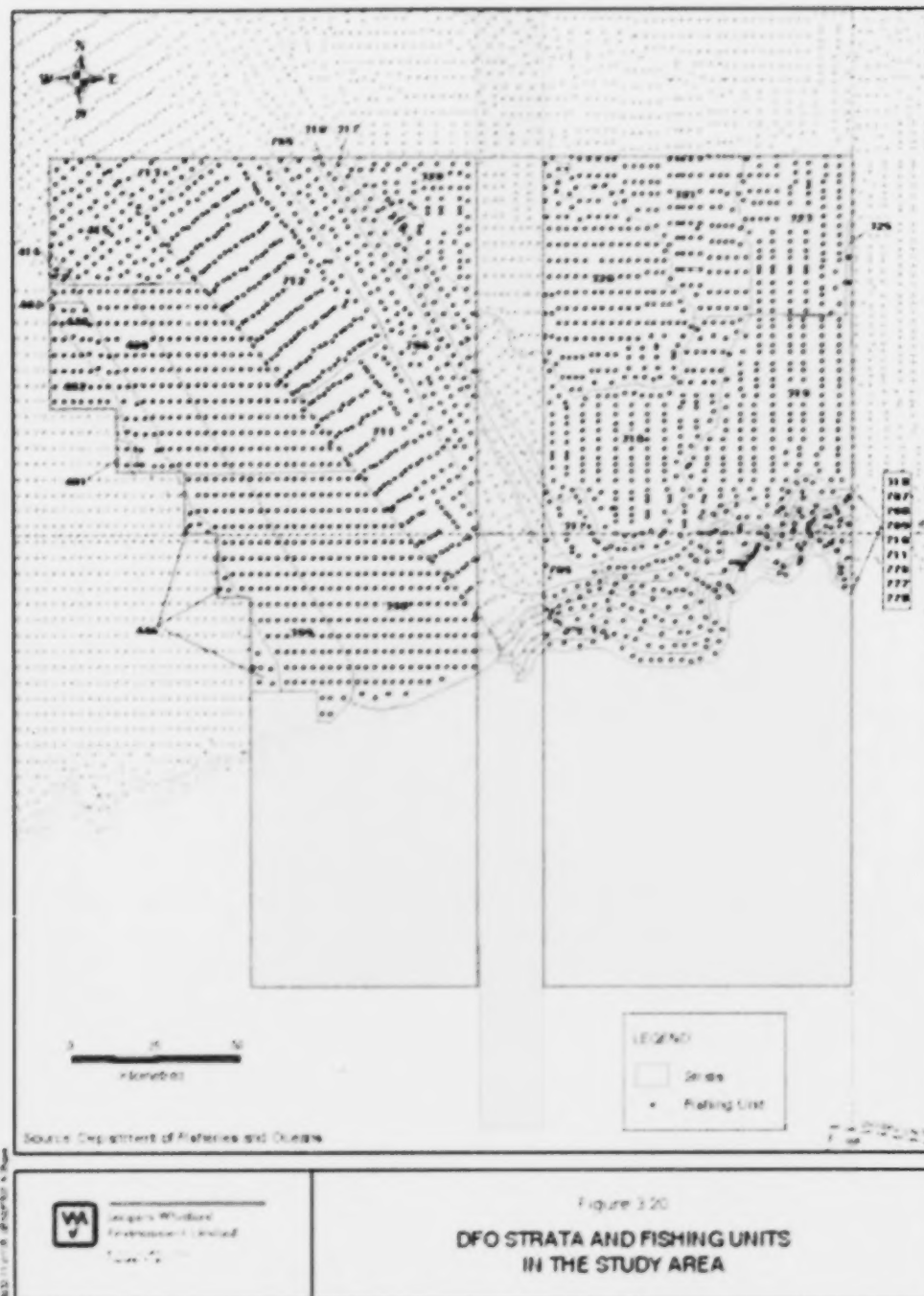
The most intensely fished areas overall include the edge of the Nova Scotia and Newfoundland shelves, the areas surrounding the Burin Peninsula/St Pierre Bank region, the area surrounding Cape Breton Island and Banquereau off Nova Scotia.

In addition to fishing vessel traffic, DFO conducts resource surveys in spring, summer and fall to assess fisheries stock status. DFO also undertakes a variety of other research-related fishing surveys throughout the year. The DFO sampling grid for resource surveys is illustrated in Figure 3.20. DFO may undertake two or more research trawls within each stratum at locations identified by fishing units. The number of research trawls within each strata is typically proportional to the size of the stratum. Maximum number of trawls within strata is in the range of 13 (spring survey - Newfoundland Region) to 17 (spring survey - Maritimes Region). Usual sampling months for Newfoundland Region are April to June (spring survey); July to August (summer survey) and September to December (fall survey).

3.3.2 Other Activities

In addition to fishing vessel movements (as described above), the study area also sees a considerable amount of other shipping activity, including oil tankers and other commercial vessels. Major shipping lanes between Newfoundland and the Maritime provinces of Canada pass through the St. Pierre Bank. The Laurentian Channel is the main route for ships entering and leaving the Gulf of St. Lawrence and the St. Lawrence Seaway. The Cabot Strait, for example, sees approximately 6,400 commercial vessel transits annually (Coffen-Smout et al. 2001). Marine transportation through the area also includes ferry traffic, recreational boating and cruise ship traffic. The ferry service between Argentia, Newfoundland and North Sydney, Nova Scotia, for example, operates from June to October, with approximately 80 crossings per year. The cruise ship industry has also grown considerably in Atlantic Canada in recent years, with approximately 70 calls at Newfoundland and Labrador ports annually in recent years, including several communities on the island's south coast (e.g., Francois, Ramea) (Department of Tourism, Culture and Recreation 2002).

Figure 3.20 DFO Strata and Fishing Units in the Study Area



From May 2002 to April 2003 there were a total of 3,801 vessel trips through the Laurentian Subbasin area (Table 3.17). The average number of trips per month over that period was 317, ranging from 248 in January to 390 in May.

The Department of National Defence has designated operational areas that cover the entire offshore region of Nova Scotia and off western and southern Newfoundland, including the whole of the Laurentian Subbasin area.

The dumping of munitions at sea was an accepted method of disposal from World War I until the 1970s. There is a single known munitions dumpsite (approximately 10 nautical miles by ten nautical miles in area) located on the southeastern edge of the study area (44°40'N, 55°00'W) (K. Penny, pers. comm.) (see Figure 6.1). Operators should consider the possibility of munitions being present in planning offshore work in the area (e.g., any "anomalies" noted during well-site surveys should be investigated prior to proceeding).

In addition to previous seismic surveys in the Laurentian Subbasin (Section 2.2.3), seismic surveys and drilling have also occurred within the French Corridor surrounding the islands of St. Pierre and Miquelon (Figure 1.1). Gulf Canada was awarded exploration rights in this region in 1998 (Penny 2000). After extensive seismic research, in March 2001 ExxonMobil Canada, Gulf Canada and Murphy Oil spudded an exploratory well in the French Corridor, approximately 160 km south of the islands of St. Pierre at Miquelon. This exploration drilling program also included the establishment of a shore base and office in St. Pierre (Doane 2001). The well did not encounter any hydrocarbons and was plugged and abandoned in late April (Anonymous 2001). However, interest in the French Corridor remains high and it is likely that seismic surveys and drilling programs will occur in the region in the future.

Table 3.17 Marine Vessel Traffic Within the Laurentian Subbasin (May 2002 – April 2003)

Vessel Type	2002								2003				Total Vessel Trips
	M	J	J	A	S	O	N	D	J	F	M	A	
Barges Oil Drilling Rig	1	0	0	0	0	0	0	2	0	1	0	0	4
Coast Guard Icebreaker	0	1	0	1	1	0	0	0	0	0	1	1	5
Coast Guard Rescue	0	1	0	0	0	1	0	0	0	0	0	1	3
Coast Guard Scientific	2	1	0	0	0	0	1	0	0	0	0	0	4
Factory Ship	0	1	2	3	2	0	2	1	2	3	4	4	24
Fishing Vessels	1	1	2	0	2	0	2	2	1	4	5	5	25
Merchant (Dry)	0	0	0	1	1	0	0	0	0	0	0	0	2
Merchant (Tanker)	68	60	70	73	59	69	71	76	72	72	70	69	829
Merchant Auto	5	2	3	3	5	4	4	4	4	5	7	4	50
Merchant Bulk	115	97	81	84	74	94	102	65	38	28	45	71	894
Merchant Chemical	6	8	4	10	8	2	5	4	9	7	8	20	91
Merchant Coastal	0	2	0	0	0	0	1	1	1	0	0	0	5
Merchant Container	96	90	73	65	61	73	68	63	65	73	86	88	901
Merchant Crude	12	10	14	13	8	16	10	17	9	11	12	13	145

Vessel Type	2002								2003				Total Vessel Trips
	M	J	J	A	S	O	N	D	J	F	M	A	
Merchant Ferry	2	2	9	11	6	1	0	0	0	0	0	0	31
Merchant Gasoline	0	0	1	0	0	0	0	0	0	0	0	0	1
Merchant General	52	54	37	42	23	47	42	28	22	26	22	27	422
Merchant Liquified Gas	0	0	2	0	0	0	0	0	0	0	0	0	2
Merchant Molasses	0	0	0	0	0	0	0	1	0	0	0	0	1
Merchant Ore	2	1	2	4	0	1	0	0	2	4	1	4	21
Merchant Ore/Bulk/Oil	6	3	1	2	0	6	3	0	0	2	3	4	30
Merchant Passenger	0	3	0	1	9	0	1	0	0	0	0	0	14
Merchant Reefer	4	3	2	5	3	4	3	2	1	1	3	3	34
Merchant RO/RO	6	6	9	12	7	6	4	8	5	5	10	11	89
Merchant Super Tanker	0	1	0	0	0	0	2	3	1	4	1	4	16
Merchant ULCC	0	0	0	0	0	1	1	0	1	0	0	2	5
Merchant VLCC	0	4	3	1	2	1	4	6	8	2	2	2	35
Special Purpose	1	1	1	1	0	1	0	0	0	0	0	1	6
Special Purpose Research VSL	0	2	0	1	6	1	1	0	0	0	0	0	11
Special Purpose Diving	0	0	0	0	0	0	0	0	0	0	0	1	1
Special Purpose Supply VSL	0	0	0	0	0	0	0	0	0	0	0	1	1
Trawler	5	0	2	2	0	0	1	0	5	5	10	6	36
Tugs	6	8	6	10	3	1	4	8	2	6	3	4	61
Yacht (Power)	0	1	0	0	0	0	0	0	0	0	0	0	1
Unspecified Vessel Type	0	0	0	0	0	0	0	0	0	0	0	1	1
Total Vessel Trips	390	363	324	345	280	329	332	291	248	259	293	347	3,801

Source: D.A. Delisle, pers. comm.

4.0 ASSESSMENT SCOPE AND METHODOLOGY

The following chapter describes the scope of the SEA, as well as the approach and methodology used to conduct the assessment.

4.1 Scope of the Assessment

A focused environmental assessment requires a process of scoping to define the components and activities which are to be assessed and the spatial and temporal boundaries of the assessment, and to identify the key environmental issues to be considered. The scope of an environmental assessment must be established early in the process to ensure that the analysis remains focussed and manageable. The following sections provide an overview of the nature and results of the scoping exercise conducted as part of this SEA.

4.1.1 Assessment Boundaries

The SEA focuses on identifying potential environmental issues and interactions which may occur as a result of potential seismic surveys and drilling programs within the Laurentian Subbasin. The boundaries of this region, specifically the area under the jurisdiction of the C-NOPB and C-NSOPB, are illustrated in Figure 1.1. The study area surrounds, but does not include, an area adjacent to the islands of St. Pierre and Miquelon (known as the French Corridor), an EEZ that is under the jurisdiction of France.

As noted in Chapter 2, some offshore exploration activities may be relatively widespread in nature (e.g., 2D seismic surveys), and may extend beyond the boundaries of individual exploration licences. In addition, as a result of the often extensive ranges and mobile nature of some environmental components, ecological and socio-economic systems also very often extend beyond such administrative boundaries. The potential for environmental interactions in areas adjacent to the study area as a result of seismic surveys, drilling programs and associated activities within the Laurentian Subbasin are therefore also considered in the SEA, as required. Although the SEA does not directly include nearshore areas within its spatial scope, potential interactions with associated vessel and aircraft traffic to and from the region are also considered.

In terms of temporal boundaries, the SEA focuses upon the "exploration phase" of offshore petroleum activity in the Laurentian Subbasin. It includes consideration of all of the components and activities that may be associated with seismic surveys and well drilling programs in the region, as described in Chapter 2 of this report. The potential for, and nature of, any possible subsequent oil and gas production activity in the Laurentian Subbasin is not known and cannot be predicted at this point. However, these possible future projects are considered to the degree possible in discussing potential cumulative environmental effects. Any petroleum production activity proposed for the region in the future would be subject to a detailed, project-specific environmental assessment.

4.1.2 Issues Scoping

Assessing all of the potential environmental issues associated with a proposed undertaking is impractical, if not impossible (Beanlands and Duinker 1983). Therefore, it is generally acknowledged that an environmental assessment should focus on those components of the environment that are particularly valued by society and/or which can serve as indicators of environmental change. These components are known as VECs, and may include both biophysical and socio-economic aspects of the environment.

Following initiation of the SEA in mid-November 2002, an initial issues scoping exercise was conducted. This process included consideration of the existing biophysical and socio-economic environments of the region (Chapter 3), and existing knowledge regarding the environmental effects of offshore seismic surveys and drilling programs. Other SEAs and generic environmental assessments undertaken in relation to offshore exploration in Atlantic Canada and elsewhere were also reviewed, including the:

- *Environmental Assessment for Exploration Drilling off Nova Scotia* (LGL Limited et al. 2000);
- *Environmental Assessment of Seismic Exploration on the Scotian Shelf* (Davis et al. 1998)
- *Strategic Environmental Assessment Parcels #1 to 9, Call for Bids NS01-1* (C-NSOPB 2001a);
- *Strategic Environmental Assessment of Potential Exploration Rights Issuance for Eastern Sable Island Bank, Western Banquereau Bank, the Gully Trough and the Eastern Scotian Slope* (C-NSOPB 2002).

Environmental assessments conducted in relation to individual seismic surveys, exploration drilling programs and development projects in Atlantic Canada and elsewhere were also reviewed, as well as available scientific studies regarding the effects of offshore seismic surveys and exploratory drilling. The results of these previous assessments and studies were also considered as part of the scoping exercise, as appropriate, with due consideration of the differences between their study areas and that for this SEA (e.g., differences in water depths, marine physiography, marine biota, etc.).

Relevant regulations and guidelines related to offshore exploration drilling offshore Newfoundland and Nova Scotia were also considered early in the assessment, including the:

- *Guidelines Respecting Drilling Programs in the Newfoundland Offshore Area* (C-NOPB 2000);
- *Guidelines Respecting Drilling Programs in the Nova Scotia Offshore Area* (C-NSOPB 2001b);
- *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NOPB 2001);
- *Geophysical and Geological Programs in the Nova Scotia Offshore Area - Guidelines for Work Programs, Authorizations and Reports* (C-NSOPB 1992);
- *OWTG* (NEB et al. 2002);

- OCSG (NEB et al. 1999); and the
- *Guidelines Respecting Physical Environmental Programs during Petroleum Drilling and Production Activities on Frontier Lands* (NEB et al. 1994).

Based on the results of this initial scoping exercise, a preliminary draft document was prepared in December 2002. This preliminary document was developed to provide the basis for further scoping through direct consultation with regulatory agencies, industry representatives, and stakeholder groups. The preliminary draft report was distributed to the following organizations for review and comment:

- Habitat Management Division, DFO, St. John's, NL;
- Environment Canada, Mount Pearl, NL;
- Resource Policy Division, Newfoundland and Labrador Department of Fisheries and Aquaculture, St. John's, NL;
- Newfoundland and Labrador Department of Environment, St. John's, NL;
- Maritime Forces Atlantic, Department of National Defence, Halifax, NS;
- Canadian Association of Petroleum Producers (CAPP), St. John's, NL;
- Fishermen Food and Allied Workers Union, St. John's, NL;
- Fisheries Association of Newfoundland and Labrador, St. John's, NL;
- Newfoundland and Labrador Natural History Society, St. John's, NL;
- Newfoundland and Labrador Protected Areas Association, St. John's, NL;
- Habitat Management Division, DFO, Dartmouth, NS;
- Environment Protection Branch, Environment Canada, Dartmouth, NS;
- Canada-Nova Scotia Fisheries and Environmental Advisory Committee (all member organizations);
- Ecology Action Centre, Halifax, NS;
- World Wildlife Fund Canada, Halifax, NS; and the
- CAPP, Halifax, NS.

Meetings were held with these individuals and groups in St. John's, Newfoundland, and Halifax, Nova Scotia on January 21 and January 24, 2003, respectively to discuss the SEA. Each organization was also invited to provide written comments on the preliminary document. The purpose of these discussions was to undertake further scoping to identify potential environmental interactions and key issues and concerns which may be associated with exploration in the Laurentian Subbasin.

The comments, questions and issues raised during this process were considered in producing a draft SEA in March 2003. On April 10, 2003 this draft report was released by the C-NOPB and C-NSOPB for public review and comment. News releases were issued announcing the availability of the draft report, and inviting public review and comment. The draft report was distributed directly to various agencies and organizations, as well as being posted in its entirety on the websites of both the C-NOPB and C-NSOPB. Public comments were accepted on the draft report until May 15, 2003.

The comments, questions and issues raised during this public comment period were considered in producing the SEA report.

4.1.3 Identification of Valued Environmental Components

As discussed previously, it is generally acknowledged that an environmental assessment should focus on those components of the environment that are valued by society and/or which can serve as indicators of environmental change, and thus, which have the most relevance to the final decision regarding the environmental acceptability of a proposal.

Based on the results of the issues scoping exercise described above, the following VECs are considered in this environmental assessment:

- fish and fish habitat;
- marine birds;
- marine mammals and sea turtles; and
- fisheries.

The rationale for the selection of these VECs is provided below.

- **Fish and Fish Habitat:** Fish resources are an important consideration in the environmental assessment of activities which may affect the marine environment. It should be noted that this rather broad VEC includes coverage of such components of fish habitat as water and sediment, plankton and benthos. Fish and their habitat are assessed as a single VEC because they are clearly interrelated. The consideration of fish and fish habitat as one VEC is in keeping with current practice in environmental assessment, and provides for a more comprehensive, ecosystem-based approach while at the same time minimizing repetition and enhancing brevity.
- **Marine Birds:** The offshore environments of Newfoundland and Labrador and Nova Scotia host a range of avifauna throughout the year. Marine birds are a key ecological component near the top of the food chain, and are an important resource for tourism and recreational activities and for scientific study. They are therefore important socially, economically, aesthetically, ecologically and scientifically. Birds are also more sensitive to oil on water than many other components of the environment.

- **Marine Mammals and Sea Turtles:** Marine mammals are key elements in the ecological and cultural environments of Atlantic Canada. Historically, seals have been an important resource due to the large annual seal hunt, and a considerable portion of the tourism industry is currently based on whale watching. There is also considerable scientific and public interest in these species, and many have designations in Canada and/or the United States as species at risk. Although sea turtles are generally uncommon, they are also considered as part of this VEC because of their endangered and/or threatened status.
- **Fisheries:** Commercial fisheries were also selected as a VEC because, historically, the fishery has played an important role in Atlantic Canada's economy, and has helped to define much of the region's character. The fishery remains an integral component of the economies of Newfoundland and Labrador and Nova Scotia. Potential interactions between offshore oil and gas operations and fisheries are key issues of concern for both industries.

Although not discussed as separate VECs, special consideration is given to any species at risk and special areas within the analysis provided for each of the VECs.

These VECs represent the key environmental components which are assessed in this document, and have formed the basis of previous environmental assessments conducted in relation to other oil and gas-related projects offshore Newfoundland and Labrador and Nova Scotia. This SEA focuses on those environmental components and potential interactions which are of primary concern, and thus, which have the most relevance to planning and decision-making related to oil and gas exploration in the Laurentian Subbasin.

The following sections describe the approach and methods used in conducting the environmental effects analysis for each of the VECs under consideration.

4.2 SEA Approach and Methodology

Through SEA, environmental considerations can be considered at the earliest appropriate stage of planning, on par with technical, economic and social considerations (Agency 2000).

SEA typically involves a relatively "broad-brush" approach to environmental assessment, focussing on general environmental issues and interactions rather than predicting specific environmental effects. At the policy, plan and program stages, specific projects and activities are usually not yet proposed or defined. Therefore, there is often little or no information available regarding the nature, timing and location of these projects and activities. SEAs are therefore typically less precise than project-specific environmental assessments (Bisset 1996). An environmental assessment of a proposed offshore exploration drilling program would, for example, consider specific project characteristics and activities (e.g., well locations; vessel routes) and predict specific environmental effects (e.g., the distribution of

drill cuttings.). SEAs, however, typically focus on more general issues, and describe potential environmental effects in much broader terms.

As noted previously, details on the specific nature and spatial and temporal distribution of potential seismic surveys and drilling programs in the Laurentian Subbasin and their environmental effects are not currently available. As discussed in Section 2.2.3, however, it is assumed that there would be a total of eight to ten wells drilled in the region during the period of the licences, with no more than two drilling units active at any given time (one in deep water and one in shallow water), with some overlap in drilling time assumed for the purposes of the SEA. It is also anticipated that there may be approximately two to three seismic program applications for the Laurentian Subbasin each year for the next couple of years, with seismic activities likely to be undertaken sequentially rather than concurrently. The specific number, location and timing of seismic surveys cannot, however, be predicted.

The purpose of this SEA is to provide a consolidation of existing, available information on the environmental setting of the Laurentian Subbasin, and to identify potential environmental issues which may be associated with these activities in the area. It identifies relevant information gaps, required activity and site-specific mitigation measures, and highlights a number of key planning considerations to reduce or avoid the identified environmental issues and interactions. The results of this assessment will be used by the C-NOPB and C-NSOPB as part of the planning and decision-making processes related to the conversion of federal exploratory permits for the Laurentian Subbasin into exploration licences. This includes decisions regarding whether to issue licences in whole or in part for an area, and/or to require general restrictive or mitigative measures for seismic and/or drilling activities.

The SEA will also provide operators with an overview of the Laurentian Subbasin's existing environmental setting, and helps to define key environmental issues and interactions which may require consideration in the early planning phases of individual seismic surveys and exploration drilling programs, as well as in their subsequent environmental assessments.

4.2.1 Potential Interactions and Existing Knowledge

This SEA focuses on the identification of general environmental issues which may be associated with offshore exploration in the Laurentian Subbasin. The analysis for each of the identified VECs includes consideration of the components and activities which are typically associated with seismic surveys and drilling programs (Chapter 2) and the region's existing environment (Chapter 3), in order to identify potential interactions between them.

As an integral part of the analyses, existing knowledge regarding the effects of offshore oil and gas activities on the identified VECs is reviewed and summarized. This section is not meant to provide an exhaustive and comprehensive review of the available literature regarding the effects of oil and gas exploration, but rather to provide some background information for the environmental effects analyses.

Given the lack of specific knowledge on the nature, location and timing of potential seismic surveys and drilling programs in the study area, potential issues and interactions are described in somewhat general terms. This section concludes with a summary of the potential environmental interactions identified, as well as an overview of general mitigation measures which are often implemented to avoid or reduce potential effects.

Follow-up programs which are typically required are also discussed where applicable.

4.2.2 Environmental Planning and Management Considerations

Based on the existing environment of the region and the potential environmental interactions and issues identified, the SEA also identifies key environmental considerations to help guide decision-making and future planning for offshore exploration in the Laurentian Subbasin to reduce or avoid environmental effects on each VEC. This section includes a summary of key information on the existing environmental setting of the area (particularly any important times, areas and sensitive species). Key planning and management considerations and additional activity, site or time-specific measures which may help to avoid or reduce potential environmental effects are also identified.

This section also provides an evaluation of the nature and adequacy of available information on the VEC in the study area, and identifies any important data gaps and information requirements.

4.2.3 Cumulative Environmental Effects

The environmental effects of individual projects and activities are not necessarily mutually exclusive of each other, but can accumulate and interact to result in cumulative environmental effects. SEA allows for an early analysis of the environmental effects of policies, plans and programs, and thus, the cumulative effects of the actions that may occur as a result of these larger decisions (Bonnell and Storey 2000). It is often only at the strategic level that the overall environmental consequences of the projects and activities which result from policies, plans and programs (FEARO 1992) can be identified (and appreciated). Cumulative effects which may result from offshore seismic surveys and drilling programs in the Laurentian Subbasin are assessed as part of analyses (based on the anticipated level of activity discussed in Section 2.2.3). For each VEC, the SEA also considers the potential cumulative effects of offshore exploration in the Laurentian Subbasin in combination with other projects and activities in the study area (i.e., general marine vessel traffic, fisheries).

5.0 ENVIRONMENTAL EFFECTS ANALYSES

5.1 Fish and Fish Habitat

5.1.1 Potential Interactions and Existing Knowledge

Potential interactions between offshore seismic surveys and drilling activities and fish and fish habitat relate primarily to:

- behavioural effects, injury or mortality due to seismic signals;
- attraction to subsurface structures and lights;
- avoidance due to noise or other disturbances;
- potential contamination due to wastewater discharges (e.g., deck drainage);
- potential smothering, contamination and habitat alteration due to the discharge and deposition of drill muds and cuttings;
- well abandonment; and
- contamination in the event of a spill or blowout.

The following sections provide a general overview of existing knowledge regarding the potential effects of offshore seismic surveys and drilling programs on fish and fish habitat. More detailed and comprehensive reviews are provided in other sources (e.g., Turnpenny and Nedwell 1994; Davis et al. 1998; LGL Limited et al. 2000; McCauley et al. 2000; Boudreau et al. 2001).

5.1.1.1 Seismic Signals

The potential effects of underwater noise due to seismic surveys include:

- tissue damage and injury due to exposure to blasts at very close range (may or may not be lethal);
- non-lethal auditory injury due to over-stimulation (at close range);
- behavioural disturbance or displacement (e.g., causing avoidance of the insonified area, or disturbance of feeding or breeding activities); and
- the masking of communication calls.

Injury and Mortality

Plankton

Experimental studies have established that gross injury and lethal outcomes likely occur only within a very short distance of airguns, where energy levels are at their highest. The energy level decays with distance from the source, so that even a few meters away (depending on source level), cellular disruption or tissue damage is unlikely.

This finding has been confirmed for a variety of planktonic life-stages, including fish eggs and larvae, and crab larvae (Table 5.1). Injuries among fish larvae are caused mainly by swimbladder over-expansion, but retinal delamination has also been reported (it should be noted that excessive reliance should not be placed upon the mortality figures reported, as handling may be a factor and the statistical significance may be doubtful).

Table 5.1 Observations from Exposures of Marine Planktonic Life Stages to Airguns at Close Range

Organism	Life Stage	Exposure Distance from Airgun (m)	Estimated Exposure Level dB re 1μPa	Observed Response	Reference
Pollack (<i>Pollachius virens</i>)	Eggs	0.75	242	Some delayed mortality	Booman et al. (1996)
Cod (<i>Gadus morhua</i>)	Larvae	5	220	Approximately 3 percent immediate mortality	
	Fry	1.3	234		
	5-day-old larvae	1	250	Delamination of retina	Matishov (1992)
Plaice (<i>Pleuronectes platessa</i>)	Eggs and larvae	1	220	High mortality (unspecified)	Kosheleva (1992)
		2	214	No effect	
Anchovy (<i>Engraulis mordax</i>)	Eggs	?	223	8.2 percent mortality	Holliday et al. in Turnpenny and Nedwell (1994)
	2-day-old larvae	3	238	Swimbladder rupture	
Red mullet (<i>Mullus surmuletus</i>)	Eggs	1	230	7.8 percent of eggs injured	Kostyvchenko (1973)
		10	210	No injuries	
Fish (various spp.)	Eggs	0.5	236	17 percent dead in 24 h	
		10	210	2.1 percent dead in 24 h	
Dungeness crab (<i>Cancer magister</i>)	Larvae	1	231	No observed effect	Pearson et al. (1992)

Various authors have attempted to estimate the potential kill rate of plankton during a seismic survey. For these estimates, it is common to assume 100 percent kill within a stated radius around the source (e.g., at the upper observed limit of mortality which is 5 m). As the array is towed along, each airgun is assumed to kill all the plankton within a 10-m diameter cylinder along the survey track. The overall mortality can then be calculated as the percentage of the entire volume of water bounded by the survey limits that has been lethally insonified by the passage of the towed array. As the plankton may be concentrated in the upper levels, this may also be taken into account.

By this means, Davis et al. (1998) estimated that up to 1 percent of the plankton in the top 50 m of the water column could be killed by a 3D survey off Nova Scotia. In a Norwegian study, Saetre and Ona (1996) estimated up to 0.45 percent losses for species concentrated in the upper 10 m, although Kenchington (2001) pointed out that they had assumed that 90 percent of the animals in question were outside the survey area; within the survey area, this equates to a 4.5 percent loss. Kenchington (2001) estimated an upper limit of 6 percent mortality under the assumption that plankton are concentrated in the upper 10 m of water, and would only rise to 7.5 percent if the plankton were concentrated in "a grossly-improbable thin layer centred at the depth of the array".

From the figures presented in Table 5.1, it is apparent that even for the ichthyoplankton component, the real mortality rate is likely to be only a fraction of this, although the range of effect could be greater than suggested where large airgun arrays are used. For the majority of other plankton, which appear not to be susceptible to seismic impulses, there may be very little mortality.

The timing and location of seismic survey activity very much influences the nature and magnitude of its effects on plankton. For example, seismic operations in the vicinity of strong seasonal stratification, frontal systems or convergent zones would at certain times of the year affect more eggs and larvae because of their higher densities. In other areas, more severe losses would occur for species with eggs, larvae and juveniles which inhabit the seasonal surface layer (Bourdreau et al. 2001).

Macroinvertebrates

Available evidence suggests that most macroinvertebrates are at little risk of injury from seismic signals. This is primarily because:

- i) few invertebrates have gas spaces, which represent the main injury loci in vulnerable vertebrate species;
- ii) as the lethal zone is within a few metres of the airguns, benthic and epibenthic invertebrate species are generally far enough away from the airguns to avoid injury (except in very shallow water (less than 20 m)); and
- iii) some species may be able to detect and avoid harmful SPLs.

The resilience of various invertebrates has been tested by exposure at a short distance from an active airgun (Table 5.2). For the above reasons, the percentage injury experienced by macroinvertebrates due to the passage of a seismic survey should be less than for planktonic organisms.

Table 5.2 Observations from Exposures of Marine Macroinvertebrates to Airguns

Organism	Exposure Distance from Airgun (m)	Estimated Exposure Level (dB re 1µPa)	Observed Response	Reference
Iceland Scallop	2	217	Shell split in 1 of 3 tested.	Matishov (1992)
Sea Urchin			15 percent of spines fell off.	
Edible Mussel	0.5	229	No detectable effect within 30 days.	Kosheleva (1992)
Periwinkle (<i>Littorina</i> spp.)				
Crustacean (<i>Gammarus locusta</i>)				
Brown shrimp (<i>Crangon crangon</i>)	1	190	No mortality.	Webb and Kempf (1992)
Gastropod (<i>Bolinus brandaris</i>)	15	186	Temporary reduction in motility; no mortality.	La Bella (1996)
Squid (<i>Sepioteuthis australis</i>)	-	174	Strong startle response, avoidance and firing of ink-sac. Alarm response.	McCauley et al. (2000)
		156 to 161		

A workshop sponsored by the Environmental Studies Research Fund (ESRF) in Halifax, Nova Scotia in September 2000 identified the potential effects of seismic activities on shellfish (particularly snow crab and lobster) as a key research priority, as little is known about their reactions to seismic noise (Thomson et al. 2000). A study of the effects of seismic activity on crab sponsored by the ESRF is currently ongoing, and should be available later in 2003.

Fish

Fish vary widely in their ability to hear sounds. Some have swim bladders connected directly to the inner ear (e.g., the herring), and are thus relatively sensitive to sound. Others do not have direct connections between swim bladder and inner ear (such as cod), and are thus less sensitive to sound than other fish species (Davis et al. 1998).

There are no records of mass fish kills associated with the operation of airgun arrays. Rise times are too slow and peak pressures too low to cause serious injury, except perhaps to fish that were within a few metres of an airgun at the time of release. Prior to coming that close to an airgun, it is likely that most fish would be driven away by the approaching noise source (Turnpenny and Nedwell 1994). The risk of this is high only in circumstances where fish are unable to avoid exposure. At slightly longer ranges, non-lethal injuries may occur, such as hearing loss, hemorrhaging of the eyes, swimbladder rupture, or stunning. ETLs for these effects are shown in Table 5.3.

Table 5.3 Effects Threshold Levels for Lethal and Injury Effects in Fish and Equivalent Distances from Airguns of Different Source Levels

Effect	ETL: dB re 1 μ Pa	Equivalent Distance from Source for Spherical Spreading (m)	
		SL = 240 dB re 1 μ Pa @ 1 m	SL = 260 dB re 1 μ Pa @ 1 m
Transient stunning	192	80-250	800-2,500
Non-auditory internal injuries	220	3-10	32-100
Egg/larval damage	220	3-10	32-100
Fish mortality	230-240	1-3	3-32
Note: Assumptions regarding spherical spreading are a generalization, used as a starting point for the consideration of possible effects. The transmission of sound energy will depend upon survey and site-specific conditions, particularly over long ranges (>1 km). After: Turnpenny and Nedwell (1994).			

Depending on the size of the airgun array and the position of the fish relative to the vessel, injuries to eyes and internal organs would occur only within a few tens of metres of the seismic vessel, with lesser symptoms such as hearing damage, possibly out to a few kilometres. However, the data for transient stunning cited by Turnpenny and Nedwell (1994) and shown in Table 5.3 were derived from experiments using continuous rather than pulsed sound (in which the total energy is lower), and may greatly overestimate the sensitivity with respect to airgun noise. These authors also present data for auditory injury thresholds (180 dB) based on continuous signal experiments, but it is likely to be misleading to apply such a figure in the context of airgun emissions. Auditory damage in fish (unlike in mammals), if it occurs at all as a result of seismic surveying, may be reversible (Song et al. 1995), although the potential for long-term hearing damage in fish exposed to seismic sources has also been noted in experimental studies (McCauley et al. 2000). Even in the case of short-term hearing effects, the fish would, in the meantime, be disadvantaged.

The potential for sub-lethal effects of seismic activity on marine organisms has been relatively uninvestigated. There are virtually no studies which have assessed exposure distance relationships for physiological and pathological effects or delayed mortality in marine organisms.

Communication

Over 50 families of fish are known to use sound for intraspecific communication (Myrberg 1981). Sound signals are used, for example, in antagonistic behaviour, warning calls and reproductive displays. Insufficient knowledge is available to assess the risk of masking by seismic noise, or its implications should this occur. The greatest risk would likely be for species that communicate by sound during reproductive rituals. The haddock is an example of this, in which the male fish emits a series of knocking, rasping and humming sounds during courtship (Hawkins 1986; Hawkins and Amorim 2000; Bremmer et al. 2002). Acoustic communication has also been identified as a potential mechanism in mate assessment by cod (Nordeide and Kjellsby 1999).

Behavioural Effects

A number of invertebrate taxa, including crustaceans, are known to be sensitive to sound. However, having no gas spaces, they do not respond primarily to sound pressure but only particle motion (vibration). Since particle motion is excited principally within the acoustic near-field of a sound source, it follows that detection by invertebrates is most likely to occur here also. The near-field equates to a range of approximately 5 m at 50 Hz and 10 m at 25 Hz. Large-scale displacements of macroinvertebrates through avoidance behaviour appear very unlikely.

Fish are sensitive to underwater sounds primarily within the 0 to 3 kHz band (Hawkins 1986). Hence, airgun emission frequencies fall within the hearing band of most fish and could be audible and, potentially, influence fish behaviour at distances where levels were sufficiently high. The effects of seismic airgun noise on fish behaviour have been investigated in a number of studies in UK, Norwegian, North American and Australian waters.

The Norwegian studies, which relate to gadoid fish (mainly cod, haddock and pollock) found fish behaviour to be affected over relatively large distances. These studies demonstrated a dispersal of fish from the survey epicentre, with density reductions of half or more over distances of kilometres or even tens of kilometres from the source. Investigations conducted by Lokkeborg and Soldal (1993) in the Norwegian Sea and Barents Sea compared catches on commercial long-line and trawling vessels that happened to be operating in the vicinity of four separate seismic surveys, in which airgun arrays of between 160 and 4,800 in³ were deployed. The output SPL was not measured but airguns of these volumes would be expected to emit peak SPLs of approximately 225 and 250 dB re 1 µPa @ 1 m, respectively (Turnpenny and Nedwell 1994). Catches were reduced over a radius of at least 9 km, although they had returned to normal within 12 hours or so. Fish appeared to be pushed out from the survey areas, allowing higher catches where the fish were temporarily concentrated around the periphery of the survey zone.

The most thorough of the Norwegian investigations was reported by Engas et al. (1993). Unlike the previous Norwegian studies, it was set up specifically as a scientific trial, and the airgun array used was deployed purely to allow the effects on fish to be determined, not for the collection of geological data. The trial was run for a total of five seismic shooting days, with control periods (no airgun operation) of seven and five days prior to and following shooting, respectively. The key findings of this study were that:

- long-line and trawl catches of cod and haddock were reduced by up to 50 percent over a radius of 30 km from the epicentre of shooting;
- acoustical densities of fish determined by echo-sounding were similarly reduced;

- fish larger than 60 cm in length were affected to a greater extent than smaller fish; and
- densities of fish in the survey area had not returned to pre-survey levels within the five-day post-monitoring period.

The sound source used in this trial was a 18 airgun array having an estimated source level of 248.7 dB re 1 μ Pa @ 1m. Water depth was up to 250 m.

Skalski et al. (1992) investigated the effects of acoustic geophysical survey devices on a commercial hook-and-line fishery for rockfish (*Sebastes* spp.) off the coast of California. A single airgun with a source level of 223 dB re 1 μ Pa was used to produce peak pressures above 186 dB re 1 μ Pa at the base of rockfish aggregations. The study found an average decline in catch-per-unit-effort of 52.4 percent under emission conditions relative to control trials, which was attributed to a change in fish aggregation height. The time period over which the effects occurred was not determined in this study, although a related behavioural experiment (Pearson et al. 1992) found that the return of rockfish to preexposure behavioural patterns occurred within minutes after sound exposures ceased, suggesting that the effects on fishing may be transitory, occurring primarily during the sound exposure itself (Skalski et al. 1992).

Turnpenny and Nedwell (1994) reviewed other studies, some of which have shown that fish reacted to seismic noise and others in which no effect was observed. Observed reactions have included avoidance of insonified waters, reduced catchability by baited-hook methods, and diving towards the seabed. ETLs for behavioural reaction to airgun noise are summarized in Table 5.4, and range from 160 to 188 dB re 1 μ Pa (average 168 dB). The predicted ranges of potential effect are shown for two airgun array emission levels.

Table 5.4 Effect Threshold Levels for Behavioural Disturbance of Different Fish Species Estimated from Field Studies and Equivalent Distances from Airguns of Different Source Levels

Species	ETL for Behavioural Disturbance (dB re 1 μ Pa)	Equivalent Distance from Source for Spherical Spreading (km)	
		SL = 240 dB re 1 μ Pa @ 1 m	SL = 260 dB re 1 μ Pa @ 1 m
Bass (<i>Dicentrarchus labrax</i>)	163	2.2-7.1	22-71
Redfish	160	3.1-10	31-100
Alewife	176, 181	0.3-1.6	3-16
Cod	160	3.1-10	31-100
Pollack	160	3.1-10	31-100
Haddock	160	3.1-10	31-100
Whiting (<i>Merlangius merlangus</i>)	188	0.13-0.4	1.3-4.0
Average / Range	168	0.13-10	1.3-100

Adapted from Turnpenny and Nedwell (1994).

These results are all for fish of "medium sensitivity", (i.e. possessing a swimbladder but with no known hearing specializations). No comparable data are available for either high sensitivity (i.e., teleost fish with swimbladders and specialized auditory couplings) or low sensitivity (i.e., elasmobranchs, and teleosts in which the swimbladder is reduced or absent) species. In using these data for predictive purposes, certain assumptions must be recognized, namely that:

- since SPLs at the observed ranges of effect were in no case actually measured in most of the above studies, the levels were accurately described by the simple spherical spreading;
- that the fish were reacting to the airgun emissions and not to some other stimulus (e.g. vessel noise); and
- the reaction was complete (i.e., that fish would not have moved even further away given more time).

Until these factors have been more thoroughly investigated, ETLs will remain uncertain. It must also be made clear that upper ranges of effect indicated have not been observed in practice, and the maximum range at which any effect on fish behaviour has been observed is in the order of 30 km, albeit at an intermediate source level between those shown.

A number of studies have also found little or no reaction by fish to seismic survey noise (e.g., Pickett et al. 1994). Wardle et al. (2001) studied the reaction of fish to seismic signals in a shallow reef area off the coast of Scotland, and looked at the responses of the reef fish (known as pollack in the United Kingdom). A Triple 'G' seismic airgun (SPL approximately 230 dB re 1 μ Pa @ 1 m) was mounted on the edge of the reef and pollack movements were observed by underwater television camera and by acoustic tagging of a few individuals. The study showed only minor changes in the pattern of behaviour as fish moved around the reef and periodically passed the airgun array, which was fired at 60-second intervals. Small pollack passing within a few metres of the array (received level probably approximately 229 dB) showed a "C-start" response but moved away only a few metres. Various factors may have contributed to the findings of these studies, such as the relatively low sound levels used, water depth (propagation conditions are poorer in shallow coastal waters) and the types of fish studied.

Although there is currently a lack of conclusive, scientific information available regarding the magnitude and extent of the effects of seismic surveys on fish behaviour in Atlantic Canada, some anecdotal information is available. On St. Pierre Bank in 1999, for example, a National Sea Products trawler reportedly experienced decreased fish catches after a seismic vessel began shooting. Captain Ernest Syme reported that on one occasion, the catch dropped from 25,000 to 30,000 pounds per tow to several thousand pounds per tow after the seismic survey commenced. However, approximately one day later the catch rate appeared to have returned to pre-shooting levels (Thomson et al. 2000).

Collins et al. (2002) also looked at potential effects on fish catches during and after two independent inshore and near-shore seismic surveys undertaken in the Bay St. George and Port au Port area of Newfoundland in the summer of 1995 and the fall of 1996. While not statistically conclusive, their analyses suggested no observable effects on overall fish catches in the region, or on snow crab catch in particular, during or in the years following the western Newfoundland inshore seismic surveys. This is further supported by the observations of local fishermen in the years since the surveys (Collins et al. 2002).

A study of the effects of seismic signals on catch rates when cod fishing and seismic activities are scheduled for the same area was also identified as an important research priority at the ESRF workshop held in Halifax, NS in September 2000 (Thomson et al. 2000).

Most of the information indicates that the effects of noise on fish are transitory, so obvious changes in behaviour may have low biological effects on fish. In most cases, it appears that scaring effects on fish as a result of a seismic operation should result in negligible effects on individuals and populations (Davis et al. 1998). The primary issue is the potential for interactions during particularly sensitive periods, such as spawning. For example, bottom-nesting species such as wolffish cannot move away without risking the loss of their egg masses to predators.

5.1.1.2 Presence of Structures

The presence of a drilling unit in offshore waters will likely attract some fish and invertebrate species (known as the "reef effect"). The structure adds diversity to the available fish habitat, especially in homogeneous soft-bottom environments. Algae accumulate on the underwater structures, attracting crustaceans and fish. Adults of migratory species (e.g., squid or capelin) and pelagic juveniles of any species may be attracted by increased food availability. Cod and haddock in the North Sea, for example, have been seen to congregate near offshore production facilities (Picken and McIntyre 1989). There is much less of a reef effect around exploratory drilling units than production rigs, as the amount of subsurface structure is less (LGL Limited et al. 2000), and because the duration of the interaction is shorter. However, this reef effect, combined with the cessation of nearby fishing activity during drilling, may temporarily increase localized productivity of some species by providing a food source (local benthos) and protection from fishing. The fish that feed on local benthos (e.g., cod, which are attracted to the structures, and invertebrate predators such as starfish, which are attracted by the presence of epifaunal prey) have the potential to alter, if not the overall density, the composition of the benthic species population (Davis et al. 1982).

There is some evidence that smaller fish attracted to a rig may be preyed upon by larger fish, even of the same species. Soldal et al. (1999) indicated some measure of cannibalism among larger cod attracted to and caught at offshore platforms. Species known to be attracted to artificial reefs occur in the study area.

Lights from drill units and seismic and support vessels may also attract some species. Shining bright lights on the water is a commercial fishing technique used to concentrate schooling species such as herring and squid. Overall, the potential attraction of fish species to exploration drilling rigs is not expected to have any measurable effect on fish populations, as it is localized and of short-term duration.

5.1.1.3 Noise (Other Than Seismic)

In addition to seismic signals, noise from drilling units, vessel and air traffic can all be transmitted through the water. There is considerable ambient noise in the ocean at all times, especially around commercial fishing areas and shipping lanes. There is also considerable noise generated by natural oceanographic conditions that can mask other non-natural noises (Buerkle 1975).

Noise from drilling activities may cause avoidance by some species. Sudden or irregular noises can scare fish and cause avoidance behaviour, but schooling behaviour is typically not affected (Blaxter et al. 1981). Fish have reportedly returned to drilling units, even though they do not seem to habituate to the irregular noises (LGL Limited et al. 2000). Short duration, low frequency noises appear to elicit short-lived directional startle responses, with longer-term avoidance responses if the noise is higher-frequency or continuous (Wilson and Dill 2002). Avoidance will likely be intermittent and short-lived, because fish are startled by sudden changes in noise levels and seem to acclimate to "ambient noise" (Misund et al. 1996). The species which are most likely to be affected are those which are attracted to the subsea structure by an increased density of food species such as invertebrates. The zone of influence associated with any such effects will also be quite small.

Continuous noise generated by a drill rig may cause prolonged avoidance by some demersal fish species from the immediate area. Avoidance by fish up to 400 m from the noisiest vessel is considered likely (ICES 1995). Physiological and reproductive effects of noise have been reported when fish are continually exposed (Clark et al. 1996). However, similar effects on non-captive fish have not been documented. Given the opportunity, fish will generally avoid areas where noise levels exceed their threshold of hearing by 30 dB or more (ICES 1995). This avoidance will likely prevent but certainly minimize any physiological or reproductive success effects, especially since avoidance will be temporary. Again, the primary issue is the displacement of fish from important spawning or feeding habitat during key periods.

5.1.1.4 Waste Water

Deck drainage (i.e., water which has reached the deck of a drilling unit through precipitation, sea spray, washdowns), may also contain hydrocarbons. Wastewater from sinks, showers, laundry and sewage, as well as sanitary and food wastes, will also be discharged from drilling rigs. The disposal at sea of other domestic wastes is not permitted, and such materials are transported to land for disposal or recycling.

The discharge of all wastewater offshore is governed by the OWTG (NEB et al. 2002). Deck drainage is typically processed through an oily water separator before discharge, and the oil component sent to shore for proper disposal. Wastewater from sinks, showers, laundry and sewage are likely to be discharged, although volumes from exploratory programs are typically low and of relatively short duration. Contamination of biota or other effects due to wastewater discharge are therefore not expected. Sanitary and food wastes are normally mulched to a maximum size of 6 mm or less, which aids in biodegradation. Enrichment or oxygen depletion of water or sediments by organic waste disposal are also not likely.

5.1.1.5 Produced Water

If significant hydrocarbons are found, the well is then evaluated and tested, which may involve formation flow testing. During testing, formation fluids, which may contain hydrocarbons and/or water, flow to the drilling unit. Produced hydrocarbons are separated from produced water on the drilling unit. However, the amount of produced water potentially encountered during exploration drilling is typically very small in comparison with that during production operations. These small amounts of produced water are sent to the flare, or treated to comply with the OWTG (NEB et al. 2002) and disposed of offshore.

The most toxic hydrocarbons present in produced water are benzene, toluene, ethylbenzene, xylene, and polycyclic aromatic hydrocarbons (PAH). PAHs are the only persistent compounds since all others evaporate very quickly. The PAHs are therefore likely the cause of reported mortalities of plankton, fish eggs and fish larvae from produced water discharges (Patin 1999). However, their zone of influence is quite limited. Initial concentrations of produced water are diluted 100-fold immediately upon release, and 1,000-fold dilution occurs within 50 to 100 m of discharge (Somerville et al. 1987; Neff et al. 1987; GESAMP 1993). Lethal effects on biota are not expected beyond a few tens of metres from the point of discharge (Somerville et al. 1987).

Produced water also has some potential to result in non-lethal effects. Recent laboratory studies have concluded that the alkylphenols present in produced water are capable of disrupting the hormonal processes in cod (Meier et al. 2002). Reduced levels of oestrogen in female cod were reported at exposures as low as 0.032 ppb for five weeks. The resulting effect was slower development of the egg and, therefore, delayed spawning. Male cod were reported to have reduced testosterone and fertilization capacity at this exposure after five weeks. Although the St. Pierre Bank is a known cod spawning area (Section 3.2.3), it is difficult to relate the findings of a laboratory study to the open ocean. Other non-lethal effects of produced water may occur as a result of heavy metals, radionucleotides or nutrient overloading. Cumulatively, untreated produced water is considered to be non-hazardous with 96-h LC₅₀ values of 0.1 to < 1 percent (GESAMP 1993). Produced water dispersion models in the North Sea predicted dilution to 0.1 percent within 50 m downstream and dilution to 0.03 percent within 250 m (Somerville et al. 1987). Therefore, non-lethal effects are not expected beyond a few hundred metres.

The potential for and nature of any such effects will clearly depend on whether fish are exposed to high enough concentrations for sufficient duration to produce an effect. This will, in turn, depend on the amount of produced water discharged. Again, if there is produced water during exploration drilling the volumes are typically very low in comparison to production operation (differing by a magnitude of two or more). Produced water resulting from exploration drilling is typically atomized with the hydrocarbons and flared. Again, any amount that cannot be sent to the flare is treated to OWTG (NEB et al. 2002) limits and discharged at depth. Individual fish may also avoid any produced water plume, which will further reduce the potential for fish being exposed to high enough concentrations for sufficient duration to result in any such effects.

5.1.1.6 Drill Muds and Cuttings

The primary issues related to the discharge and deposition of drill muds and cuttings include: deposition (smothering habitat, creation of piles, extent of deposition); toxicity (based on the chemical constituents of the mud); bioaccumulation (i.e., uptake of hydrocarbons by fish and the perception of taint); and physical effects (i.e., exposure of organisms to fine waste particles).

Drill cuttings are usually a few centimetres in diameter but a small portion of finer material may also be released. The release of the cuttings initially creates a plume of particles suspended in the water for several seconds. Depending on the currents, most of the cuttings will fall within a few metres of the discharge point, with the finer material remaining in suspension longer and being dispersed over a wider area. The area affected will depend upon site-specific oceanographic conditions. Cuttings typically form a doughnut shaped mound centred on the well. The ultimate size and depth of the cuttings pile depends on the volume of cuttings released, their grain size, water depth, and subsequent reworking by currents or wave action. Smothering of sessile benthic organisms will result if the thickness of the cuttings layer exceeds 1 cm (Bakke et al. 1989). Boudreau et al. (2001) note that although operational discharges may cause biological effects over relatively short time periods and within small distances from the source, effects are site and program-specific. They go on to conclude that smothering of benthic organisms by deposited mud and cuttings would not be anticipated outside of an approximately 0.5-km radius from the drill rig.

Cutting piles can be recolonized and return to an original state once they have been buried by normal sedimentation or dispersed by physical means. Current speed and sedimentation rates in the study area are variable, so the time required for complete recovery of a depositional area would vary accordingly.

Water-Based Drilling Muds

During drilling of the initial part of a well, WBM and drill cuttings are discharged directly to the seafloor because the riser is not yet in place to transport them back to the drilling unit. Discharge of WBM is approved under the OWTG (NEB et al. 2002), as they are considered non-toxic.

The major components of WBMs are bentonite and barite, with particle sizes up to 10 and 40 μm , respectively. Settling rates in seawater are usually in the range of 0.1 to 0.5 cm/s. WBMs are typically discharged in 100-kg pulses as the hole is drilled. The concentration of WBM continues to decrease as the plume disperses. Depending on the area drilled and the local current regime, these particles may be carried several kilometres before settling out. Benthic invertebrates and demersal fish that are in the area of the plume will be exposed to WBMs for several minutes during each release. Initial concentrations of WBMs at release are estimated to be in the 100 to 200 ppm range. WBM components typically have a 96-h LC_{50} for fish and invertebrates in the 100,000-ppm range (Thomas et al. 1984). However, heavy metals in used WBMs (alone or in combination with other components) may affect sensitive species in the immediate vicinity of drilling rigs (Kenchington 2001). The two most sensitive groups in the study area are likely scallops and sea corals.

The effects of WBM-associated drill cuttings are believed to be relatively minor, restricted in geographic scope, and relatively short-lived (i.e., a few years in well-mixed shallow areas (Neff et al. 1989; LGL Limited et al. 2000; United Kingdom Department of Trade and Industry 2002)). Boudreau (1998) determined that the area affected by the discharge of WBMs from isolated exploration wells in the high energy environment of Georges Bank would be limited to the area under and adjacent to the rig, and that there would be no significant effects on species such as scallop. However, Boudreau (1998) determined that there was some potential for effects in less energetic areas on Georges Bank (which is more comparable to areas in the Laurentian Subbasin). In low energy areas, smothering of benthic organisms could result due to the accumulation of discharged drill cuttings (Boudreau et al. 1999; Gordon et al. 2000).

Discernible effects of the discharge of WBM from a single well on benthic communities are typically limited to an area within a few hundred metres from the source (LGL Limited et al. 2000), and are reversible once drilling ceases (Boudreau et al. 1999).

WBM cuttings have been reported to have no effect on recolonization of cuttings piles (Bakke et al. 1989b). Recovery of baseline abundance of macrobenthos can occur within 11 months in a 1,240 m water depth (Kukert and Smith 1992). Currents aid in cuttings dispersion as well as supplying larvae and juveniles for recolonization. Opportunistic species that may be tolerant of pollutants, such as some polychaetes and nematodes, will likely colonize an oil-based mud cuttings pile within months (Kingston 1992); the same should hold true for a WBM cuttings pile. Mobile benthic organisms (e.g., shrimp) quickly recolonize a disturbed area if water quality is not permanently affected (Levings 1982). Benthic feeding fish (e.g., flounder) will likely soon follow the recolonization of prey species such as polychaetes and nematodes.

Sessile deposit feeders (e.g., some polychaete species) may accumulate metals from the WBM (Neff et al. 1989). Mobile benthic feeders (e.g., flatfish) are not expected to accumulate metals from WBM because they will likely avoid the immediate area of drilling activity. Once drilling ends, benthic feeders

may return to the area and be exposed to a spatially-limited area of metals above background concentrations. The level of exposure is not expected to cause chronic or acute toxicity.

Concern has been raised that elevated concentrations of barite and bentonite in the water may affect the growth, reproductive success and survival of sensitive species, in particular, sea scallops (Cranford and Gordon 1992; Cranford et al. 1999; 2001). Chronic effects on scallop growth and reproduction were observed at bentonite concentrations as low as 2 ppm, with death ensuing at levels above 10 ppm. Scallop mortality was observed at barite levels below 0.5 ppm. However, these conclusions are based on laboratory experiments (which were based on modelling and field observations) with prolonged exposure (72 days) of adult scallops at high concentrations (as discussed in Section 2.2.2.4, the drilling of a single exploration well can require 30 to 120 days, with most taking about 45 days). However, the studies also did not account for active wind and tidal mixing, and changed biophysical bottom characteristics. The concentration of fine particulate matter also changes following phytoplankton blooms, during intense zooplankton grazing, and storm-induced aggregation/flocculation (Kepkay 1994; Muschenheim and Milligan 1996; Kiørboe 2001).

Cranford et al. (1999) noted that scallop growth was enhanced by a mixture of fine WBM cuttings particles at concentrations less than 10 mg/L, presumably because of increased food availability from organic matter adsorbed onto the particles. Interestingly, scallop veliger larvae are much less sensitive than adults (Cranford et al. 1998), perhaps because of their similar weight to barite and bentonite particles; however, the reason remains unknown. The apparent sensitivity of adult scallops to barite may be related to it causing physical damage to their gills rather than toxicological mechanisms (Barlow and Kingston 2001). The potential for effects on scallops is more likely to be an issue for drilling activity on the St. Pierre Bank than in the Laurentian Channel or on the slope, given the distribution of the spring and summer scallop fishery (Appendix C).

Corals are particularly sensitive to changes in the sediment load in the water column. An increase in the amount of sedimentation, such as produced by drill muds, could reduce the growth of corals and other filter feeders. A large increase in sedimentation can kill coral colonies by stimulating increased mucous production, eventually killing the corals. Aside from sedimentation, oil and gas exploration could alter current and nutrient flow around coral colonies, increasing the amount of environmental stress on the corals. This will make the colonies more susceptible to bacterial infection, another cause of coral mortality (Breeze et al. 1997). Because of their slow growth rate in deep, cold waters, coral colonies in the study area will take longer to recover from damage than tropical coral colonies. Studies on Alaskan cold-water coral colonies suggest that it would require from 10 to 100 years for a coral colony to recover if damaged by oil and gas exploration (Cimberg et al. 1981).

Deep-sea corals are found in the study area in the Laurentian Channel, along the slopes at depths of 293 m or greater, along the Stone Fence, and on the southern edge of the St. Pierre Bank (Section 3.2.2.2). These species are extremely long-lived, taking several hundred years to grow a few metres in

height. Because of this slow growth rate, recovery from any adverse effects could require up to 100 years. Heavy, fine sediments can slowly smother the coral. The ability of corals to deal with increased sediments is species-specific. Branching species, such as the ones found off eastern Canada, are effective in passively rejecting sediment through their morphology. However, sediment readily settles on species with broad flat surfaces (Bak 1978, Cimberg et al. 1981; Dustan and Halas 1987, cited in LGL Limited et al. 2000).

There is little information concerning the effects of sedimentation (i.e., smothering with deposited sediment, in this case, WBM cuttings) on the coral species known or likely to be found in the study area. Experiments on tropical round, plate-shaped corals found that exposure to 100 ppm of used WBM caused reduced respiration, calcification, feeding, growth, and some mortality. Exposure to 1 and 10 ppm had none of these effects. Exposure to 1,000 ppm was fatal within 65 hours in three of seven species tested (Dodge 1982; Dodge and Szmant-Froelich 1985, cited in LGL Limited et al. 2000).

Synthetic-Based Drilling Muds

SBMs may be used in drilling lower well sections if the use of water-based fluids is technically impractical. The SBMs are returned to the deck of the drilling unit, where the cuttings and mud are separated. The cuttings are treated to comply with the OWTG and then discharged below the water surface; however, some mud is retained on the cuttings.

SBMs have been developed to avoid the toxic effects associated with oil-based drill fluids. The primary effects of SBMs are expected to be organic enrichment and sediment oxygen depletion. Their potential for toxicity is generally low, but this varies among drilling fluid types. During typically short exploratory drill programs, smothering of benthic organisms and nutrient enrichment of the sea bed may occur between 50 to 500 m from the drilling rig (ERT 1996; EPA 1999a; 1999b, cited in LGL Limited et al. 2000).

An SBM commonly used in exploration is PureDrill IA-35, a synthetic alkane that has very low toxicity. This fluid consists of isoalkanes and cycloalkanes from C12 to C20. Alkanes of this molecular size are not known to produce irritation of living tissues, nor cause any biological effects since they are metabolized by sediment-dwelling organisms, and no persistent toxic metabolites are formed. There are no effects of bioaccumulation, and no evidence of fish tainting (Kiceniuk 1999). Payne et al. (2001a; 2001b) demonstrated that IA-35 had very low acute toxicity to different life stages of several invertebrate and fish species; however, it is uncertain how these in situ results translate to field conditions. Payne et al. (2001a; 2001b) also indicated that the chronic and cumulative effects of SBMs and/or WBMs are unknown. Production-phase EEM programs may provide answers to these unknowns. The physical habitat within the footprint of the SBM cuttings pile will be altered until natural physical process restore the substrate to its original condition. Currents will disperse cuttings and bring in larvae and juveniles for recolonization. Recolonization by mobile demersal species will occur quickly if

adverse water quality does not persist (Levings 1982), and benthic-feeding fish will return following recolonization by prey species such as polychaetes and nematodes. Other echinoderms, amphipods, harpacticoid copepods and scallops may require two to three years to colonize cuttings piles if there is any measurable contamination remaining (Peterson et al. 1996).

5.1.1.7 Well Abandonment

Upon completion of a drilling program, wells are typically abandoned. Operators would likely attempt to remove wellheads by mechanical means, in which the well is plugged and the well casing is cut and removed just below the surface of the seafloor. An ROV is then used to inspect the seabed. There is typically little interaction with fish and fish habitat during the mechanical separation and recovery of wellheads.

In the unlikely event that this method proves unsuccessful, underwater explosives would be used to remove the wellhead. In this case, charges are lowered into the casing and detonated (usually 1 to 10 m below the sea substrate). These charges are typically in the range of 16 to 20 kg (35 to 45 lb) (Howorth et al. 1996; Howorth 1997).

Explosions differ from continuous noise in that they have rapid rise times and produce both an acoustic and shock-wave components (Greene and Moore 1995). Pulse rise time is very brief (within approximately a microsecond). The broadband source level of a 20-kg charge is approximately 279 dB re 1 μ Pa, with dominant frequencies below 50 Hz (Richardson et al. 1995). A charge detonated below the seafloor will have an initial rate of increased pressure somewhat more attenuated than an explosion in the water column. Much of the initial shock pulse and energy from the explosion is absorbed by the seafloor.

The shock waves produced by high explosives are more damaging to fish than those produced by airguns (Davis et al. 1998). The magnitude and timing of the explosion will usually determine the potential effect of underwater explosives on fish and fish habitat. There would be mortality in the infaunal community in the substrate immediately above the blast site. Water column effects would be dependent upon the life stage and abundance in the immediate vicinity of a blast site. Lethal effects would be more likely to occur in juvenile fish and shellfish than adults, with the threshold of a lethal effect to a juvenile up to 10 times lower than for an adult (Side 1992). Effects ranging from light hemorrhaging of juvenile body cavities to temporary disbursement of adults can occur in the immediate vicinity of an explosion, with tissue damage occurring up to 600 m from a blast site (Nedwell et al. 2001). Fish mortality was observed at 25 percent of 16 well head sites monitored during explosions by Nedwell et al. (2001).

Goertner (1981) determined that for a 56-lb (25-kg) severance explosion buried 4.6 m (15 feet) in a mud bottom in 61 m (200 feet) water depth, measurable fish kills can occur near the surface out to a horizontal range of 27 m (90 feet), with larger fish considerably less vulnerable to injury. Near the bottom, significant fish kills of all sizes of fish were predicted to be limited to a maximum horizontal range of approximately 21 m (70 feet). It was found that in water depths of 152 m (500 feet), the hazard is considerably reduced, and is probably significant only for small fish, with no measurable kills in water depths of 305 m (1,000 feet). The nature and potential effects of the use of explosives during wellhead removal is discussed further in Section 5.3.1.

Given the potential environmental effects associated with these underwater explosions, operators are encouraged to ensure that the design of wells and casings will facilitate the effective mechanical cutting and removal of the wellhead.

5.1.1.8 Accidental Events

An oil spill may result from a surface or subsea blow-out or an accidental discharge from the drilling platform or associated vessel. Although a spill is unlikely, released hydrocarbons affect water quality, which in turn may affect fish eggs and larvae and, possibly, juvenile and adult fish. The nature and severity of such an interaction will depend on the magnitude, timing and location of the spill.

The potential behaviour of an oil plume from a surface or subsurface spill is highly variable, and depends on physical and chemical parameters such as water temperature, wind and wave energy at the time of the spill (Section 2.2.2.6). The properties of the spilled product, and the water depth and pressure at which it is released are also fundamental in determining the resulting effects.

In the unlikely event of a spill, water quality would be degraded within the affected area. Oil would not coat the seafloor, nor would it likely cloud the water column for a long time or large area. Juvenile and adult fish can detect oil-contaminated water, but may or may not avoid it, depending on such factors as migration impulse or concentrations of toxic components (Rice 1985, cited in LGL Limited et al. 2000).

The oil from an above surface or subsea blow-out would settle on the surface of the water. Depending on the timing and magnitude of the event, fish eggs and larvae near the surface in the area could be adversely affected. The result of such an interaction would depend on the circumstances. Fish eggs and larvae have a high natural mortality, and the magnitude of an effect on such a population would depend on whether the effect is density dependent or independent, and what proportion of the spawning stock is affected. If, for example, a stock or population spawns at one specific site, and that site is subject to a spill (or accidental dump of drilling fluids), then the magnitude of effect within the stock or population could be high. If a stock or population spawns in more general areas (i.e., non-specific locations), then the resulting effect of a spill on fish would likely be of low magnitude, and not likely affect fish populations in any measurable way.

5.1.1.9 Summary

A summary of the activities likely to occur in association with seismic surveys and exploration drilling programs in the Laurentian Subbasin and potential interactions with fish and fish habitat is provided in Table 5.5. The table also provides examples of general mitigation measures which may be implemented to avoid or reduce any adverse effects on fish and fish habitat, as well as a number of compliance standards which may apply to such activities. Table 5.5 is not intended to be comprehensive or prescriptive, but rather provides a general summary of typical interactions and mitigation at a level of detail appropriate for an SEA. Project-specific effects vary depending on the nature, location and timing of individual projects and activities, and mitigation measures will be determined by the C-NOPB and C-NOPB in assessing specific seismic surveys and exploration drilling programs.

Table 5.5 Potential Environmental Interactions and Mitigation Summary – Fish and Fish Habitat

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
SEISMIC SURVEYS		
Air Gun Operations	possible injury, mortality or avoidance	- minimization of airgun source level - use of "soft-start" procedures - avoidance of sensitive areas and times
Vessel Traffic	- possible avoidance - discharges causing contamination	minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
DRILLING		
Planned Activities		
Vessel Traffic	- possible avoidance - discharges causing contamination	- minimization of traffic volume - use of existing and common travel routes where possible - minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
Aircraft Traffic	possible avoidance	- avoid low-level operations - minimization of activity
Presence of Structures / Lights	possible attraction	
Over-the-side Discharges		
- Sewage, Deck Drainage, Bilge/Cooling Water, Wash Fluids	- contamination, taint, bioaccumulation - decreased water quality - habitat alteration	- compliance with 2002 OWTG - chemical screening and selection - use of an oily water separator to process contained deck drainage; collected oil shipped to shore - shipping of all solid and hazardous waste to onshore disposal facilities
- Drill Cuttings	- smothering of benthic communities - contamination, taint, bioaccumulation - decreased water quality - habitat alteration	- use of WBM's where possible - use of low-toxicity drilling fluids - treatment of SBM-associated drill cuttings to compliance with 2002 OWTG prior to discharge - chemical screening and selection
Discharges at Depth		
- Drilling Muds (WBMs)	- smothering of benthic communities - contamination, taint, bioaccumulation - decreased water quality - habitat alteration	- compliance with 2002 OWTG - chemical screening and selection
- Drill Cuttings		
Atmospheric Emissions (Exhaust, Gas Venting/Flaring)	particulate deposition on water	use of high efficiency burners

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
Well Testing	contamination	- atomize produced water with hydrocarbons in flare - compliance with 2002 OWTG
Well Abandonment		
- Mechanical Separation	n/a	
- Chemical Explosives	blasting effects (if required)	- use of mechanical separation where possible - design of well and casings to ensure effective mechanical cutting and recovery - scheduling of blasting - setting charges below the sediment surface - minimize amount of explosives used - use of high velocity explosives - minimize number of consecutive blasts per group of detonations - staggering of individual blasts
Unplanned Events		
Fuel/Oil Spills (surface and subsurface)	- toxicity and bioaccumulation - plankton kill - decreased water quality	- prevention and design considerations - oil spill preparedness and response procedures

Environmental compliance monitoring (including reporting on waste discharges, emissions, and treatment systems) is required to verify adherence to applicable legislation and any conditions of regulatory approval.

In the unlikely event of an accidental spill or blowout, appropriate response procedures would be activated, and a spill environmental effects monitoring (EEM) program would be implemented. Site-specific oceanographic information (i.e., currents, winds) is needed to accurately predict the spill trajectory of possible accidental events in the case of specific exploration drilling programs.

5.1.2 Environmental Planning and Management Considerations

The following section highlights a number of key planning and management considerations related to potential seismic surveys and drilling programs in the Laurentian Subbasin. It also identifies key information gaps and requirements.

5.1.2.1 Species at Risk

A number of species at risk occur within the Laurentian Subbasin, and should be given special consideration in planning and decision-making regarding offshore exploration in the area. Atlantic cod occur throughout the St. Pierre Bank and Laurentian and Halibut Channels during winter, with a portion of the population migrating to more inshore areas during the summer months. Cusk are also found in the area year-round. Three species of wolffish also likely occur year-round in the deeper waters of the study area (northern, spotted and Atlantic wolffish), each of which have been listed by COSEWIC. The Atlantic wolffish is likely the more abundant of the three species in the region, occurring primarily in the

Laurentian Channel in spring and in lower numbers along the slope. A number of other species which are included on COSEWIC's Prioritized Candidate List also occur within the study area (e.g., redfish).

Atlantic cod spawn within the study area (St. Pierre Bank and Halibut Channel (NAFO Unit Areas 3Psf, 3Psg, 3Psh) in the March to June period. Cusk likely spawn along the southwestern slope of the Laurentian Channel from May to August, with peak spawning occurring in June. Although it is not known with certainty whether any of the three wolfish species spawn within the study area, spawning likely occurs in the region given the limited migration of these species. Spawning takes place in the fall period (September to November). If spawning does occur in the Laurentian Subbasin, it would most likely take place on the slope of the St. Pierre Bank, as a colonial activity on underwater ledges. In addition, redfish spawn along the shelf of the St. Pierre Bank and in the deeper waters of the channel, with live young released from April through July.

Where possible, seismic surveys should be scheduled to limit interaction with known spawning times and areas, or to avoid potential spawning times for these species.

As well, there are COSEWIC status reports being prepared for the following species occurring in the study area: barndoor skate, Acadian redfish, blue hake, porbeagle, roughhead grenadier, roundnose grenadier, spinytail skate, and winter skate. These new reports are either under review (blue hake, porbeagle, roughhead grenadier, roundnose grenadier, spinytail skate, and winter skate) or in draft preparation (barndoor skate and Acadian redfish); and are not considered final until a species is designated at a Species Assessment Meeting, indicated to be either May 2004 (Acadian redfish, blue hake, porbeagle, roughhead grenadier, roundnose grenadier and spinytail skate), May 2005 (winter skate) or a date not yet determined (barndoor skate) (COSEWIC 2003b).

As discussed in Section 3.2.3.2, the Canadian *Species at Risk Act* received royal assent in December 2002, and came into force in 2003. The Act is intended to protect species at risk in Canada and their critical habitat, and may have implications for planning and assessing offshore exploration in the region. Depending on the specific activity proposed and its location and timing, additional information may be useful in determining whether listed species and critical habitat are present and likely to be affected by proposed seismic surveys and drilling programs. In cases where species or habitats protected by the *Species at Risk Act* are known or expected to occur, the mitigation of any such effects will be an important consideration in decision-making related to offshore exploration.

5.1.2.2 Other Special Areas and Sensitive Times

In addition to the above, a number of other species are known or likely to spawn within the study area. As indicated in Section 3.2.3, spawning times vary considerably, with some species spawning primarily in the spring to early summer (e.g., American plaice, Atlantic cod, redfish), some during the summer months (e.g., haddock, white hake, mackerel), some in the late summer and fall (e.g., pollock, wolfish)

and others during winter (e.g., Greenland halibut, porbeagle shark). Information on the documented spawning locations for these species and the duration of the planktonic life stage for each species is also provided in Section 3.2.3.

The Laurentian Subbasin also serves as an important migration route for a number of fish species. For example, during the fall, redfish migrate out of the Gulf of St. Lawrence through the Cabot Strait and into the Laurentian Channel, where they overwinter, returning to the Gulf of St. Lawrence in the spring. Atlantic salmon migrate through the area from spring to fall on their way to and from summer feeding areas off Labrador and Greenland. In addition, shelf edges and bank slopes may be highly productive areas (e.g., the west side of the St. Pierre Bank), and are therefore often critical locations for spawning and feeding fish, as well as birds and marine mammals.

As indicated in Section 3.2.3, a range of fish species inhabit the study area at various times of the year. The region is characterized by a complex spatial and temporal pattern of seasonal occurrences and distributions, migration patterns, and spawning times and locations, as well as complex ecological relationships within and between species. Generally, most species produce eggs and larvae during the spring, but larval and pelagic juveniles remain in the water column through most of the summer.

Given the diversity of spawning and migration times, durations and locations within the Laurentian Subbasin as a whole, and the somewhat broad level of information available regarding specific locations and times, it is difficult to specify particular periods and sites which may be particularly sensitive. Certainly, planning for individual seismic programs should include consideration of the potential for fish spawning and migration in the general area. Scheduling should consider fish spawning and migration times and locations, and where possible, be conducted so as to reduce potential interactions.

A number of forthcoming information sources on fish spawning in the region will be very useful in planning and assessing individual proposed seismic programs to avoid or reduce potential interactions. DFO is currently completing an Environmental Studies Research Funds (ESRF)-funded project to map fish spawning locations and times on the Grand Banks. Maps are being generated for select finfish and shellfish species to show the locations and seasonality of spawning and nursery areas, using DFO-research vessel survey data. The final ESRF Technical Report is expected in mid-2003. DFO is also currently working on a similar ESRF-funded study to identify the locations and timing of spawning and nursery areas for various finfish and shellfish species on the Scotian Shelf. The final report for this study is expected in late 2003.

5.1.2.3 Marine Benthos and Corals

A range of water depths and substrate types are present within the Laurentian Subbasin, which suggests the presence of a variety of benthic communities. Benthic animals form an important food source for many species of marine biota. A number of shellfish species also have considerable commercial

importance in the study area, with fisheries for snow crab, deep-sea and Iceland scallop and clams being among the most lucrative in the region in recent years.

Deep-sea corals are also an important consideration in relation to potential drilling programs in the region. Coral aggregations are of considerable scientific and public interest, and provide habitats for a diverse benthic community. These, in turn, are an important food source for bottom-dwelling fish species, many of which are of commercial importance. As discussed previously, corals are particularly sensitive to increases in sedimentation in the water column due to drilling activities or other disturbances. Deep-sea corals are known or thought to occur in parts of the Laurentian Subbasin area (existing information on corals is summarized in Section 3.2.2.2). The Stone Fence is, for example, known to be such an area and the only known area with living *Lophelia* on Canada's Atlantic coast was confirmed in the Stone Fence area in September 2003..

However, there is an overall lack of existing information on marine benthos within the study area. The information which is available, although useful, is sparse and somewhat dated. Similarly, little research has been conducted on corals in Atlantic Canada, and their distribution in the Laurentian Subbasin is not well known at present. Overall, there is a need for more information on the biological and ecological associations of species found in the deeper waters of the Laurentian Subbasin area. As the recently discovered *Lophelia* reef is located in unlicensed lands, future decisions on seismic and exploration activities should fully take their presence into account.

Environmental assessments for specific exploration drilling programs may include dispersion modelling for drill muds and cuttings discharges, based on detailed project information and site-specific physical oceanographic data. These provide information on the volume of muds and cuttings which will be released, the size of the depositional area and thickness of the cuttings pile and settling times, which would assist in the assessment of the potential effects of individual drilling programs on marine benthos, corals and fish.

Additional, site-specific environmental baseline data may also be required in relation to proposed drilling programs in the Laurentian Subbasin. Given the lack of existing, available information on marine benthos in the study area, collection of site-specific benthic data as part of regulatory approvals processes for specific drilling programs may be required (including, where possible, the collection of sediment samples for chemical analysis). A pre-drilling ROV investigation of bottom conditions would provide additional information on the natural habitat (e.g., sediment characteristics, presence of any deep-sea corals, the potential for sensitive cool-vent benthic communities) in the vicinity of the drilling location before drilling operations take place.

In cases where drilling activities are proposed in or adjacent to areas where aggregations of deep-sea corals or other sensitive features may occur (e.g., the Stone Fence), the area of these surveys may be expanded to include the zone of influence of drill muds and cuttings discharges (as determined through

detailed dispersion modelling) to determine whether corals are present and likely to be affected. Should aggregations of corals or other sensitive features be found within the zone of influence of proposed drilling activities, additional mitigation may be required, such as restrictions on the at-sea discharge of waste material.

In addition, post-drilling monitoring programs may be required. This may include a visual survey of the seafloor and sediment sampling around the wellsite to verify pre-drilling predictions regarding the extent of the cuttings pile and resulting effects on benthic organisms. This information is useful in comparing seafloor disturbances when post-drilling clean-up and site inspections are completed. The respective Board may require that a post-drilling report be submitted for each drilling program.

Although existing information and that which may be gathered through site-specific surveys and assessments will be of use in planning specific drilling programs in the study area over the short-term, overall, there is a lack of information on marine benthos and deep-sea corals in the Laurentian Subbasin at present. A number of forthcoming information sources will, however, add considerably to this knowledge base. For example, video surveys were conducted by DFO at 48 stations in the Laurentian Channel, along the southern edge of the Grand Banks and off the Stone Fence in 2002. The information collected in these surveys is currently being processed, and it is anticipated that the data will be available in early 2004. Preliminary reports indicate that 11 species of corals were found, with the greatest diversity at the Stone Fence. Once available, this will represent an important source of information for planning and assessing drilling activity in the Laurentian Subbasin.

Given the considerable scientific and stakeholder interest in these species, other government and industry-funded research programs may also consider exploring this issue more fully (such as those conducted through the ESRF, the Panel on Energy Research and Development (PERD), or Petroleum Research Atlantic Canada (PRAC)).

5.1.3 Cumulative Environmental Effects

Cumulative environmental effects may occur as a result of offshore seismic surveys and drilling programs in the region in combination with each other, and with other projects and activities in the area.

As noted previously, details on the specific nature and spatial and temporal distribution of potential seismic surveys and drilling programs in the Laurentian Subbasin and their environmental effects are not currently available. As discussed in Section 2.2.3, however, it is assumed that there would be a total of eight to ten wells drilled in the region during the period of the licences, with no more than two drilling units active at any given time (one in deep water and one in shallow water). Drilling activity at any one site in the study area will also be of relatively short-term duration. The zones of influence of individual drilling programs are therefore unlikely to interact spatially and/or temporally with others in the study area (although some overlap in drilling time is assumed for the purposes of the SEA). It is anticipated

that approximately two to three seismic surveys may be conducted annually over the next few years in the region. Seismic activities would likely be undertaken sequentially rather than concurrently, and would not likely occur in close proximity to each other or to ongoing drilling operations. However, the often spatially extensive nature of these surveys (especially in the case of 2D surveys), increases the potential for interactions between the effects of individual programs. In addition, good sound propagation is likely in portions of the Laurentian Subbasin (especially the deeper channel areas). The widespread and migratory nature of many fish species and populations also increases the potential for cumulative environmental effects to occur.

Consideration of cumulative environmental effects will therefore be an important part of regulatory planning and decision-making regarding offshore exploration in the Laurentian Subbasin. This will minimize the potential for spatial and temporal interaction between individual seismic surveys and/or drilling programs in the area and their effects, and thus, minimize the potential for cumulative effects, particularly during sensitive periods.

Fish in the study area have been affected by other past and ongoing development activities in the region and other parts of their often extensive ranges, particularly commercial fishing activity (as described in detail in Section 3.3.1). The negative effects of commercial fishing, especially trawling in deep water, on fish and fish habitat are well known (ICES 2000). Fish resources on the St. Pierre Bank area in particular have traditionally been under considerable pressure. There are also indications that bottom trawling has considerably reduced the coral population in the Stone Fence area (Auld 2002). Past and ongoing vessel traffic in the area has also likely contributed to effects on fish and fish habitat.

Although the potential for and possible intensity of offshore oil and gas development activity in the Laurentian Subbasin will depend on the results of seismic surveys and drilling programs in the region, such development is possible. Depending on the location and timing of any such development activity in the region, the effects of any such projects could result in cumulative environmental effects in combination with seismic surveys and exploration drilling programs in the region. Again, the location and timing of any potential offshore oil and gas development activity in the region is unknown at this point.

5.2 Marine Birds

5.2.1 Potential Interactions and Existing Knowledge

Potential interactions between offshore seismic surveys and drilling programs and marine birds include:

- the attraction of birds to lights on vessels and drilling rigs and to flares;
- disturbance and changes in distribution due to vessel and aircraft activity and the presence of structures;
- effects due to exposure to loud instantaneous noises during seismic exploration; and
- bird mortality as a result of accidental releases from drill rigs and vessels.

The following sections provide a discussion of each of these potential interactions, including an overview of existing knowledge regarding the potential effects of offshore petroleum exploration on marine birds.

5.2.1.1 Lights, Flares and Traffic

The potential effects of routine offshore activities on marine birds relate primarily to lights, flares and vessel and aircraft movement.

A number of observers and researchers have noted the attraction of birds to offshore platforms. Following the establishment of a platform in the Bering Sea, bird densities were six to seven times higher than those previously observed in the area (Baird 1990). Tasker et al. (1986) noted higher densities of birds within 500 m of a platform in the North Sea than in the surrounding waters. Wiese and Montevecchi (2000) noted that marine bird concentrations around offshore oil platforms on the Grand Banks were 19 to 38 times higher than on survey transects leading to the platforms.

Birds that are attracted to offshore installations may experience mortality through strikes against infrastructure or incineration in flares. Birds may also become disoriented by lights and have been observed flying continuously around them, consuming energy and delaying foraging or migration (Avery et al. 1978; Bourne 1979; Sage 1979; Wiese et al. 2001). This disorientation appears to occur most frequently during periods of drizzle and fog, conditions that often occur in offshore areas. Moisture droplets in the air during conditions of drizzle and fog refract the light and greatly increase the illuminated area, thus enhancing the attraction (Wiese et al. 2001). While mortality does occur from bird strikes at offshore installations, generally the number of individuals involved appears to be low. During monitoring aboard a Terra Nova vessel over a three-week period during the summer of 1998, 52 Leach's storm petrels were recovered and released with no mortality observed (Husky Oil 2000). While there is an association of birds with offshore oil platforms, the degree, nature, timing and extent of associated mortality is generally unknown (Montevecchi et al. 1999).

Similarly, while birds appear to be attracted to flares, incidences of mortality appear to be uncommon. During surveys of bird attraction to a flare on an offshore platform in the North Sea, it was noted that marine birds (mainly fulmars and gulls) were attracted to the surface of the sea directly below the flare at night and appeared to be feeding on the surface. However, only one bird was observed flying near the flame during the five-week autumn (late September and October) observation period. No bird mortality was observed as a result of the flare, indicating that it is possible for large numbers of birds to be attracted to flares without mortality occurring (Hope-Jones 1980). Other North Sea installations have reported mortality from gas flares, but the numbers are usually low (Sage 1979; Hope-Jones 1980). Flaring, if required at all during exploration drilling, is typically an intermittent and short-term activity only.

Marine bird reactions to vessels and aircraft are complex and depend on a number of factors, including the species involved, previous exposure levels, and the location, altitude and number of movements (Hunt 1985, cited in MMS 2001a). Aircraft and supply vessel routes are not anticipated to occur in close proximity to known colonies of marine birds. Aircraft associated with offshore exploration typically fly at an altitude and speed that limits the potential for interactions with marine birds offshore. Birds using the general area are already likely somewhat habituated to noise and disturbance from vessel traffic, as there is considerable fishing activity and cargo vessel movement through the area at present.

5.2.1.2 Seismic Signals

Deep-diving birds may be at risk of damage or disruption of foraging activity when exposed to underwater airgun noise during seismic exploration. It is unlikely that non-diving species, such as gulls, would be affected by airguns. There is little information available on the effects of high underwater noise levels on diving birds. Turnpenny and Nedwell (1994) refer to data on three species (guillemot, fulmar and kittiwake) that were monitored by trained observers during the course of seismic surveys using airguns. No individuals appeared to show ill effects. There have been no investigations of possible auditory effects on birds (Turnpenny and Nedwell 1994). Bird auditory systems are broadly similar to those of other vertebrates, and presumably would be vulnerable to over-stimulation and consequent hearing loss. Unlike fish or marine mammals, diving birds place their heads under the water suddenly in pursuit of prey and could potentially be exposed to high noise levels, without the benefit of a steady gradient. Consequently, they would find it difficult to predict or avoid excessively high levels.

Deep-diving birds such as the alcids (e.g., dovekies, puffins) which may be particularly sensitive to seismic activity are most common in the Laurentian Subbasin during the winter months (September to April).

5.2.1.3 Drilling Discharges and Emissions

Other potential effects relate to the chronic release of oily water through discharges such as deck drainage, bilge water, etc. Discharges from offshore drilling rigs must be managed in accordance with the OWTG (NEB et al. 2002) (Section 2.2.2.5). Hydrocarbon concentrations associated with these discharges are therefore not generally associated with formation of a surface slick and, thus, should have no measurable effect on marine birds.

Underwater discharges, such as drill cuttings, will not interact directly with marine birds, although any effects to the fish species upon which these avifauna depend (Section 5.1) may also indirectly affect this VEC.

5.2.1.4 Accidental Events

An accidental release of hydrocarbons can result in external exposure of birds to oil at the water surface. This exposure may cause a loss of waterproofing, thermoregulatory capability (hypothermia) and buoyancy (drowning) due to the matting of feathers (Montevecchi et al. 1999; MMS 2001a; Wiese et al. 2001). Oil may also be ingested from excessive preening/cleaning (of even slightly oiled feathers (Stout 1993)), resulting in lethal and sublethal effects due to compromised physiological systems, including starvation due to increased energy needs to compensate for heat loss resulting from oiling and loss of insulation (Peakall et al. 1980; 1982; MMS 2001a).

There is no direct relationship between the volume of oil spilled and bird mortality, rather, it is the timing and location of spills that primarily influence mortality rates (Wiese et al. 2001). The effects of an accidental oil spill would be dependent on the time of year, sea conditions, the volume and type of material spilled, and type of spill (i.e., surface or sub-surface). Effects would only occur if birds are in the immediate area and, as described previously, the particular species present in the region varies considerably according to season. However, the effects of an accidental oil spill on pelagic birds could be considerable within the zone of influence of a spill.

Alcids are likely most vulnerable to oil spills as they spend considerable time sitting on the surface of the water. These species occur in the area primarily in the winter period (September to April), when low water temperatures may also slow down degradation or weathering of spilled oil.

Typically, the fate of surface discharges is influenced by prevailing winds and currents. The behaviour of oil in water is a function of oil properties, well flow characteristics and depth of water, all of which influence the size of oil droplets when they reach the surface. If oil droplets that reach the surface are small in size, dispersion may occur more quickly, decreasing the potential effects of the slick on birds. Oil spill trajectory modeling conducted by LGL Limited et al. (2000) indicated that spills in the study area would likely disperse before reaching land (Section 2.2.2.6).

Although there is the potential for effects to marine birds as a result of a large offshore oil spill, the probability of such an event occurring is extremely low. The nature and degree of such an effect will depend on the size, location and timing of the spill. Oil spill prevention, preparedness and response plans by individual operators will ensure that the possibility, and effects, of any such events are minimized.

5.2.1.5 Summary

A summary of the activities likely to occur in association with seismic surveys and exploration drilling programs in the Laurentian Subbasin and potential interactions with marine birds is provided in Table 5.6. The table also provides examples of general mitigation measures which may be implemented to avoid or reduce any adverse effects on marine birds, as well as a number of compliance standards which may apply to such activities. Table 5.6 is not intended to be comprehensive or prescriptive, but rather provides a general summary of typical interactions and mitigation at a level of detail appropriate for an SEA. Project-specific effects vary depending on the nature, location and timing of individual projects and activities, and mitigation measures will be determined by the C-NOPB and C-NSOPB in assessing specific seismic surveys and exploration drilling programs.

Table 5.6 Potential Environmental Interactions and Mitigation Summary – Marine Birds

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
SEISMIC SURVEYS		
Air Gun Operations	effects to some diving bird species	- minimization of airgun source level - use of "soft-start" procedures
Vessel Traffic	attraction and disturbance	minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
DRILLING		
Planned Activities		
Vessel Traffic	attraction and disturbance	- avoidance of bird colonies and large aggregations of avifauna - minimization of vessel traffic - minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
Aircraft Traffic	disturbance	- avoidance of bird colonies and large aggregations of avifauna - minimization of activity - avoidance of low-level operations
Presence of Structures / Lights	- attraction and disturbance - stranding	collection and release of birds stranded on installations
Over-the-side Discharges		
- Sewage, Deck Drainage, Bilge/Cooling Water, Wash Fluids	- bird mortality - effects on prey species	- treatment of operational discharges prior to release in compliance with applicable guidelines (OWTG) - screening of chemicals through the OCSG
- Drill Cuttings	effects on prey species	- use of WBMs where possible - treatment to compliance with 2002 OWTG - chemical screening and selection

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
Discharges at Depth		
- Drilling Mud (WBMs)	• effects on prey species	• compliance with 2002 OWTG • chemical screening and selection
- Drill Cuttings	• effects on prey species	
Atmospheric Emissions (Exhaust, Gas Venting/Flaring)	• bird mortality	• use of high efficiency burners
Well Testing	• bird mortality and effects on prey species	• atomize produced water with hydrocarbons in the flare • compliance with 2002 OWTG
Well Abandonment		
- Mechanical Separation	• n/a	
- Chemical Explosives	• effects of blasting (if required) • effects on prey species	• use of mechanical separation where possible • design of well and casings to ensure effective mechanical cutting and recovery • scheduling of blasting • setting charges below the sediment surface • minimize amount of explosives used • use of high velocity explosives • minimize number of consecutive blasts per group of detonations • staggering of individual blasts
Unplanned Events		
Fuel/Oil Spills (surface and subsurface)	• bird mortality • effects on prey species	• oil spill prevention • oil spill preparedness and response plans

The implementation of standard mitigation measures (Table 5.6) would reduce any potential effects to marine birds as a result of seismic surveys and drilling programs in the Laurentian Subbasin. The collection and release of stranded birds is one such measure to reduce the potential effects of the presence of offshore installations and their associated lights on marine birds during normal operational activities. General guidance information for handling marine birds is available (e.g., Williams and Chardine 1998). Authorization for implementing such protocols is required from the Canadian Wildlife Service. Additional activity, site or time-specific mitigation measures may be required, depending on the timing and location of such activities.

Environmental compliance monitoring (including reporting on waste discharges, emissions, and treatment systems) is required to verify adherence to applicable legislation and any conditions of regulatory approval. In the unlikely event of a spill or blowout, an operational oil spill contingency plan would be activated. A post-spill EEM program for marine birds may be a specific aspect of the response plan.

5.2.2 Environmental Planning and Management Considerations

5.2.2.1 Occurrence and Spatial and Temporal Trends

Marine birds are present in the Laurentian Subbasin year-round, with many species moving in and out of the area at different times of the year. Information on the seasonal occurrence of avifauna in and near the Laurentian Subbasin is presented in Section 3.2.4 and summarized in Figure 3.6. As the study area is offshore, there are no seabird colonies or nesting areas in the immediate vicinity. Marine birds presence within the study area is generally associated with individuals or groups moving through the area during migration periods (generally in the spring and fall) and during the winter months (September through April), when congregations of species such as murres and dovekies may occur offshore.

Although specific, detailed information on the spatial distribution of marine birds and particular species in the study area is not available, some generalizations and trends can be noted. For example, areas such as the western edge of the St. Pierre Bank and the shelf break, which are likely characterized by upwelling and mixing water masses, may support relatively large numbers of marine birds that are attracted to the phytoplankton and zooplankton communities that provide abundant forage.

5.2.2.2 Species at Risk

A number of species at risk occur in the Laurentian Subbasin or adjacent coastal areas. The harlequin duck occurs off Cape St. Mary's and along the southern and eastern shores of Nova Scotia in winter. The piping plover nests at beaches in southern Newfoundland, along the coast of Nova Scotia and on the island of Miquelon in summer. The roseate tern breeds in small numbers on several islands off the coast of Nova Scotia. The most likely times for potential interactions with these species in the study area would be during the spring and fall migration periods, generally mid-April through May and late-August through September. The ivory gull is an uncommon winter vagrant and is usually associated with pack ice.

As discussed in Section 3.2.3.2, the Canadian *Species at Risk Act* came into force in 2003, and is intended to protect species at risk in Canada and their critical habitat. The Act may have implications for planning and assessing offshore exploration in the region. Depending on the specific activity proposed and its location and timing, additional information may be useful to determine whether listed species and critical habitat are present and likely to be affected by proposed seismic surveys and drilling programs. In cases where species or habitats protected by the *Species at Risk Act* are known or expected to occur, the mitigation of any such effects will be an important consideration in decision-making related to offshore exploration.

5.2.2.3 Information Availability

Overall, there continues to be a limited amount of detailed information on the spatial and temporal distribution and abundance of avifauna species offshore Newfoundland and Labrador and Nova Scotia. As such, the presence and abundance of a species at any one location within the study area at any given time is not known. However, existing, available information on marine birds in the region does allow for a general understanding of marine bird occurrence and spatial and temporal trends.

Operators may also develop and implement operational monitoring programs for marine birds during offshore exploration programs. This has included bird monitoring during exploration drilling programs off Newfoundland and Labrador, as well as during seismic surveys off Nova Scotia. Protocols for monitoring birds at sea are currently under review, and a standardized methodology is being established. Any information gathered through such observations would, over time, contribute to the overall knowledge base regarding the presence, abundance and spatial and temporal distribution of marine birds in the Laurentian Subbasin.

5.2.3 Cumulative Environmental Effects

Specific details on the nature and spatial and temporal distribution of potential seismic surveys and drilling programs in the Laurentian Subbasin and their environmental effects are not currently available. For the purposes of the SEA, it is assumed that there would be eight to ten wells drilled in the region during the period of the licences, with no more than two drilling units active at any given time (one in deep water and one in shallow water). It is anticipated that approximately two to three seismic surveys may be conducted annually over the next few years in the region.

Potential effects to marine birds as a result of routine activities relate primarily to lights, flares and vessel and aircraft movement. The anticipated level of exploration in the Laurentian Subbasin and the relatively short-term nature of these actions will likely mean that seismic surveys and drilling programs (and possibly, any development projects) will likely be separated enough in space and time that a "reef effect" from drill rig and vessels lighting should not occur (i.e., marine birds would not perceive multiple structures as a continuous string of stimuli). This will, of course, depend on the eventual intensity and spatial and temporal distribution of these activities. The widespread and migratory nature of many marine bird species also increases the potential for cumulative environmental effects.

The distribution and abundance of marine birds may be influenced by natural processes such as weather, food availability and oceanographic variation, as well as by human activities such as fishing, vessel traffic, large offshore structures and pollution (Wiese and Montevecchi 2000). Vessel movements associated with fishing activity and general marine traffic throughout the region, as well as previous offshore exploration, may have, to varying degrees, affected marine bird populations in the study area. Hunting activity, both legal and illegal, also puts pressure on some bird populations. In addition to these local disturbances, migratory bird species may also be affected by a range of activities and associated effects within their often very extensive ranges, including hunting, pesticides and other pollution.

5.3 Marine Mammals and Sea Turtles

5.3.1 Potential Interactions and Existing Knowledge

Potential effects on marine mammals and sea turtles that may result from seismic surveys and exploratory drilling relate primarily to:

- noise, that may cause
 - avoidance of certain areas that would otherwise be used by the individuals affected,
 - interference with vocal communication between individuals,
 - attraction of some individuals to the sound source, putting them at risk of collision or contamination, and
 - temporary impairment or permanent injury of hearing apparatus from extremely loud sounds;
- potential contamination of marine mammals and sea turtles and their food sources as a result of discharges; and
- the potential effects of accidental spills.

A general discussion of the potential effects of seismic exploration and offshore drilling on marine mammals and sea turtles is provided in the following sections. More detailed information can be found in other reviews (e.g., Turnpenny and Nedwell 1994; Richardson et al. 1995; Davis et al. 1998; LGL Limited et al. 2000; McCauley et al. 2000).

5.3.1.1 Seismic Signals

Of the various activities which are typically associated with offshore exploration, seismic surveys are generally rated as having the greatest potential for effects to marine mammals and, possibly, sea turtles.

The level of sound energy produced varies, and sound propagation is largely determined by area-specific oceanographic characteristics. The attenuation characteristics of noise in the Laurentian Subbasin may be complex, owing to the range of bottom topographies involved (Section 3.1.1). In shallower shelf areas (like the Eastern Scotian Shelf and, by inference, the St. Pierre Bank in the study area), sound propagation is dampened. Less is known about propagation in deeper areas such as the Laurentian Channel, although sound is likely to propagate further in deeper waters, especially where acoustic channels exist.

Marine Mammals

Given the practical and ethical considerations associated with experimenting on marine mammals, there is no direct evidence regarding the possible injury effects of airgun emissions. For the most part, gross injuries caused by blast effects are considered unlikely at the relatively low impulse strengths generated by most airgun arrays (Richardson et al. 1995), and potential effects are limited primarily to the risk of auditory damage. Although these injuries are unlikely, auditory damage could, potentially, be debilitating by compromising hearing or navigational abilities.

Temporary threshold shift (TTS) is hearing deterioration due to prolonged or repeated exposure to high noise levels. TTS can last from minutes or hours to days. The magnitude of TTS depends on the duration and level of noise exposure, among other things (Davis et al. 1998). However, specific TTS thresholds are not known and there is very little published information on TSS in marine mammals (Davis et al. 1998), particularly in relation to full airgun array sounds.

One study of TTS levels in odontocetes (bottlenose dolphin) (Ridgway et al. 1997) concluded that the received levels of seismic pulses would exceed the TTS threshold of that species only at distances substantially less than 100 m from the beam of the array. Thresholds for TTS in baleen whales remain essentially unknown and it cannot be assumed that such results would apply to these species, which seem to be much better adapted to low frequency hearing and thus, may be more sensitive to possible effects due to seismic signals. However, it is likely that most individual baleen whales avoid the relatively small zone around a seismic vessel within which effects on hearing may occur, although given their observed presence in the vicinity of seismic arrays, it is possible that some seals may occur close enough to be affected (Davis et al. 1998).

Behavioural Effects - Cetaceans

Potential non-injury-related effects are behavioural and would arise from animals being disturbed or confused by noise emissions, or from the masking of communication between animals. Indirect effects could also arise from displacement of prey by noise emissions or by noise masking the sounds generated by prey species.

Cetacean Hearing and Predicted Ranges of Airgun Noise Detection

The hearing abilities of odontocete whales have been studied for a number of species held in captivity. Maximum sensitivity of odontocetes (e.g., killer and beluga whales, harbour porpoise) lies between 10 and 100 kHz, and is therefore well above the main emission band of an airgun array (Richardson et al. 1995). Fewer studies have been conducted for effects to hearing at frequencies below 1 kHz. Tyack et al. (1993), for example, played low frequency noise (800 to 900 Hz, source level 150 to 170 dB re 1µPa

@1 m) to bottlenose dolphins and saw little reaction to either pulsed or continuous sounds. Nevertheless, some species have been shown capable of detecting frequencies down to less than 100 Hz.

As in fish, threshold levels given in cetacean audiograms cannot be used directly to predict detection of airgun noise. The signal's duty cycle and the background noise must also be taken into consideration. Richardson et al. (1995), for example, show a hearing sensitivity of approximately 130 dB re 1 μ Pa at 100 Hz in beluga whales. This might suggest that a signal of source strength 255 dB re 1 μ Pa @ 1 m could be heard at a distance of 1,800 km (assuming simple spherical spreading). Given the low duty cycle of the signal (approximately 0.3 percent) and ambient noise, the detection range, and absorption, which becomes important at longer ranges, in practice it is likely to be heard at between one-tenth and one-hundredth of this value (18 to 180 km), but this would need to be evaluated by acoustic modelling or measurement.

No similar auditory studies are available for the mysticete (baleen) whales, which include all of the great whale species. From indirect evidence of vocalization spectra for baleen whales, which are generally in the subsonic range (10 to 20 Hz) (Evans and Nice 1997), it is inferred that their hearing must be sensitive in this lower range. Richardson et al. (1995) estimated that baleen whales would be able to hear airgun emissions from seismic ships at more than 100 km away.

Odontocetes

There is little documented reaction of odontocetes to airgun noise. Seismic operators occasionally report dolphins swimming close to airgun arrays (Duncan 1985; Chamberlain 1985; Stronach 1993). In these instances, the animals have been observed at ranges of between 50 m and 2 km of the seismic vessel during shooting. This would concur with the poor hearing ability at airgun emission frequencies (mainly less than 150 Hz), although higher frequency components are also emitted, albeit at lower levels. However, other species may be more sensitive. Richardson et al. (1995) cite cases of sperm whales in the Gulf of Mexico moving approximately 50 km away during seismic surveying and, in the southern Indian Ocean, ceasing calls when seismic shooting was taking place up to 300 km away (noise level +10 to 15 dB above background). Similarly, Stone (2001) found that sightings of some species (e.g., white-sided dolphins) decreased considerably during periods of seismic shooting.

Information from United Kingdom waters is provided by Evans and Nice (1997), who reviewed unpublished studies undertaken by Baines (1993) and Goold (1996b) during a seismic survey carried out off the coast of West Wales. Baines (1993) made regular counts of harbour porpoises off Strumble Head over the months preceding a seismic survey undertaken in October-November 1993, and noted a temporary absence of them the day that shooting began. However, numbers returned to pre-survey levels within a week and remained so during the rest of the three-week survey. No estimate of source levels or exposure levels was given. Goold's (1996b) study, undertaken for Chevron United Kingdom during a 2D seismic survey in October-November 1994 monitored cetacean calls using hydrophones. Acoustic

contact with odontocetes declined during the survey period, and 86 percent of contact with dolphins occurred when the airguns were silent. However, Evans and Nice (1997) report that common dolphins migrate southwards at that time of the year, which may account for their disappearance during the survey. They also cite a further study undertaken by Goold (1996a) at the same time the following year (1995) when no seismic testing occurred, showing a similar marked reduction in dolphin activity after September.

In the Moray Firth, one of Britain's best-known habitats for bottlenose dolphin, 40,000 km of seismic survey lines were shot between 1965 and 1994 without apparent harm (Turnpenny and Nedwell 1994). Behavioural reactions and movements out of areas of high seismic activity in the Gulf of Mexico have been reported by Mate et al. (1994). However, a study conducted in The Gully did not find any obvious changes in the behaviour or distribution of sperm whales in response to seismic activities (McCall Howard 1999).

Therefore, the evidence for seismic survey effects on odontocetes is not conclusive. Given a lack of definitive data, it is not feasible to estimate an ETL for odontocete behavioural change, although it is likely to be considerably less than that for baleen whales. The impression given by the studies undertaken so far is that seismic testing may cause transient disturbances, but that odontocetes will voluntarily come close to operating seismic vessels, perhaps as Goold (1996b) has suggested, when the rewards of feeding are high enough. Davis et al. (1998) concluded that the zone of behavioural effect on the Scotian Shelf for odontocetes may be approximately 1 km in radius.

A summary of observed reactions of whales to seismic airguns is provided in Table 5.7.

Table 5.7 Observed Reactions of Cetaceans to Airgun Emission Levels

Species	Observed Reaction	SPL (dB re 1µPa)
Sperm whale	Ceased calling.	+10 to 15 dB above ambient
Grey whale	10 percent probability of avoidance. 50 percent probability of avoidance. 90 percent probability of avoidance. Turned away from source, moved away, increased respiration rate.	164 dB 170 dB 180 dB >160 dB
Bowhead whale	Avoidance behaviour, reduced surfacing, longer intervals between blowing. Some change in surfacing -respiration- diving behaviour.	152-178 dB 125 to 133 dB
Humpback whale	Startle response. Avoidance behaviour.	150-159 dB > 172 dB
Source: Richardson et al. (1995)		

Mysticetes

Studies on the reactions of baleen whales have been reviewed by Richardson et al. (1995) and Evans and Nice (1997). They concern, principally, observations of bowhead and grey whales off the coasts of North America during the course of seismic testing. A variety of reactions has been seen in both species. These include startle responses on start-up of the airguns, avoidance of insonified areas close to the source, changes in diving-surfacing-respiration behaviour and changes in communication calls. Apparent avoidance responses have also been noted in other baleen species, including humpback and blue whales. Clear avoidance appears to occur at ETLs of approximately 160 to 170 dB re 1 μ Pa (approximately 12 to 25 km away from the source for SL=255 dB re 1 μ Pa) in all species, although these are invariably inferred rather than measured levels. Individual whales may react at lower noise levels, with the lowest estimate for avoidance by grey whales being 115 dB re 1 μ Pa.

Aerial observations made when a seismic survey was being conducted in the Alaskan Beaufort Sea showed that actively migrating bowheads avoided an active seismic vessel by as much as 20 to 30 km, where received sound levels were calculated to be 116 to 135 dB (Richardson et al. 1999). Malme et al. (1986; 1988) showed that 50 percent of grey whales in the Northern Bering Sea ceased feeding when they received a peak pressure level of 173 dB re 1 μ Pa. This corresponded to an area within 2.8 km of the seismic vessel. Humpback whales in Australia exhibited avoidance behaviour up to 8 km away from a seismic survey, primarily maintaining a distance of 3 to 4 km from the active array (McCauley et al. 1998). However, pods of fin whales have been observed feeding within 4 km of a seismic survey, which may indicate that disturbance was negligible at this distance (Moscrop and Swift 1999). The studies to date indicate that such disturbances are likely to be transitory with normal behaviour resuming within an hour or two after ship passage (Davis et al. 1998).

Behavioural responses by marine mammals to seismic activity have been observed in United Kingdom waters and adjacent areas (Stone 1997; 1998; 2000; 2001). Stone (2001), for example, noted an increased tendency for cetaceans to engage in fast swimming and breaching, jumping and somersaulting during periods of seismic shooting. This increased tendency was evident at distances of up to 4 km or more of the source for breaching, jumping and somersaulting and at distances of up to 3 km for fast swimming. It was also noted that positive interactions of cetaceans with seismic survey vessels or equipment (e.g., following or approaching the vessel) occurred considerably more often when the airguns were not firing.

Cetacean Communication

When background sound levels are augmented by human activity, such as ship and seismic noises, acoustical communications and interception may be a problem as vocalizations may be masked (Myrberg 1990). Data on communication frequencies of cetaceans were reviewed by Evans and Nice

(1997). Odontocetes principally use frequencies of greater than 1 kHz (i.e., above the main emission band of airguns). Thus, there would appear to be little potential for masking, except at very close range. Baleen whales, on the other hand, do communicate using "moaning" sounds (as well as using higher frequency calls of various types) that have frequencies in the tens or hundreds of Hz, hence that overlap with airgun spectra. Therefore, communication is most likely to be interrupted in these species (JNCC 1998).

Given the short duty cycle of a seismic pulse (approximately 0.03 seconds every 10 seconds), interference with cetacean communication may not be as important as at close range. At longer ranges, masking may become more important as the signal becomes drawn out and emissions from multiple sources and signal paths may combine. These effects may be even more relevant to marine mammals with extended calls (such as many baleen whales) which could thus be affected by several seismic shots. In addition, seismic sounds may also mask prey sounds, which could adversely affect feeding success in some species.

Behavioural Effects - Seals

Underwater hearing of phocinid seals is characterized by a relatively flat response over the range 1 to 30 kHz. Hearing sensitivity has not been measured at frequencies below 1 kHz, except in one harbour seal, whose 100 Hz threshold was 96 dB re 1 μ Pa (Kastak and Schusterman 1995). This is approximately 30 dB lower than known odontocete hearing thresholds at 100 Hz, so that seals should be able to detect seismic noise at much longer ranges (20 to 40 times) than odontocetes. The low duty cycle, and the presence of background noise would, in practice, increase the detection threshold for detection of seismic noise.

Richardson et al. (1995) reviewed data on reactions of pinnipeds to man-made underwater noise. They found some evidence of a startle response in the South African fur seal when close to an airgun, but it was ineffective in driving them away from fishing gear. In another case, grey seals were found not to show a strong reaction. It was concluded that seals are tolerant of seismic noise, perhaps habituating quickly, and are not afraid to enter insonified areas to feed.

Radio telemetry was used to study movements in harbour and grey seals around a seismic survey conducted in United Kingdom waters (Thompson et al. 1998). The airgun array comprised three guns with a total volume of 90 in³. Behavioural reactions were variable. One harbour seal avoided the array at ranges of up to 2.5 km and ceased feeding while the airguns were active. Another did not react, even at 500 m distance from the array. Grey seals exposed to a 10-in³ airgun showed avoidance reduced foraging but returned to the foraging area after the cessation of shooting.

It should also be noted that the available information on short-term reactions (or lack thereof) of marine mammals to noise does not provide insight into any potential long-term effects on habitat use, feeding and other activities (Davis et al. 1998), particularly in cases where seismic activity is concentrated within a given area over a period of time. Even short-term avoidance of an area by small cetaceans (e.g., the harbour porpoise), for example, where high metabolic demands require frequent feeding, displacement to an area of reduced food availability could be important. In addition, while most of the known, observed effects of seismic surveys on marine mammals occur primarily in the general vicinity of the source and appear to be relatively short-term in duration, less is known about the manner in which less intense, prolonged sound exposures affect marine life.

Sea Turtles

There is little information available on the effects of seismic exploration on sea turtles (Davis et al. 1998). There do not appear to have been instances of gross injuries or mortalities reported for sea turtles in the vicinity of a seismic survey.

Moein et al. (1994) report that loggerhead turtles suffered temporary hearing loss (TTS) when exposed to airgun emissions within a 65 m range. Two weeks later, their hearing had returned to normal. Eckhert et al. (1998) predicted that the hearing of leatherback turtles could be damaged at ranges of up to 3 km from a seismic survey. Sea turtles are sensitive to sound over a similar frequency range to many fish species. Green turtles have maximum sensitivity at frequencies of 300 to 500 Hz, possibly extending from 60 to 1,000 Hz (Ridgway et al. 1969). Loggerhead turtles hear over 250 to 1,000 Hz, with maximum sensitivity towards the lower end of this range, and possibly lower.

There is evidence that turtles avoid areas of seismic airgun emissions. McCauley et al. (2000) report that loggerhead turtles experimentally exposed to airgun noise showed avoidance at received SPLs of 166 dB re 1 μ Pa. O'Hara and Wilcox (1990) attempted to use airguns to exclude turtles from unsafe areas. The turtles maintained a stand-off distance of at least 30 m from the airguns (SPL=220 dB re 1 μ Pa @ 1 m). Assuming spherical spreading, this would equate to a received SPL of 190 dB re 1 μ Pa, although in shallow water the level at this range may have been lower.

Summary of the Potential Effects of Seismic Signals

The potential effects of noise emitted by seismic surveys on marine mammals and sea turtles relate primarily to possible auditory damage and potential behavioural effects. Specific TTS thresholds are not known, and there is very little available information on TSS in marine mammals. However, it is likely that most individuals would avoid the relatively small zone around a seismic vessel within which effects on hearing may occur.

The hearing sensitivity of the majority of species of odontocete whales is well above the main emission band of a seismic airgun array and, therefore, there is little chance of behavioural effects on this group. Some species of odontocetes have been reported swimming close to airgun arrays, while others have been observed avoiding seismic vessel activity and ceasing calling. Although there is no empirical evidence that baleen whales can detect noise emitted by airguns, research has suggested they could detect noise emitted from seismic ships at more than 100 km away. Behavioural observations of baleen whales have included startle responses, avoidance of seismic survey areas by tens of kilometres, changes in diving-surfacing-respiratory behaviour, and changes in communication calls. Although study results are not conclusive, it appears that the effect of seismic activity is limited to temporary disturbance, with displaced individuals reoccupying an area following the cessation of seismic activity.

Seals are generally thought to be tolerant of seismic noise, habituating quickly, and entering insonified areas to feed. For those species observed avoiding seismic survey areas, a return to the foraging area after the cessation of shooting was also observed. Sea turtles have been observed to avoid the immediate areas of operating airgun arrays, and loggerhead turtles have been reported to experience temporary hearing loss.

5.3.1.2 Vessel and Helicopter Traffic

Reported ship collisions with whales are considered to be relatively rare events in light of the frequency of both whales and shipping movements in many parts of the world (Laist et al. 2000). However, there is some potential for seismic survey vessels or supply vessel traffic to collide with marine mammals during offshore exploration activities, particularly slower-moving animals (e.g., northern right whale).

The reactions of cetaceans to ships may be avoidance, approach, or indifference (Richardson et al. 1995). Where there is a pattern of ship movements within a specific area (e.g., repeated transits by supply vessels to platforms, or by ferries, whale research, and tourism vessels), resident marine mammals become familiar with the noise signature, direction and speed of individual vessels. They habituate to ships following a consistent course or frequently present in the area (Richardson et al. 1995).

Erbe (2002) modelled effects on killer whales of boats producing sound levels from 145 to 169 dB re 1 μ Pa @ 1 m, depending on speed. Fast boats could be audible at 16 km, mask whale calls at up to 14 km, elicit a behavioural response over 200 m, and cause a temporary hearing-threshold shift of 5 dB after less than an hour. A number of slow, closely encircling boats could, in combination, produce permanent hearing loss with very prolonged exposure.

As discussed under seismic signals, noise, especially sudden changes in frequency or intensity, can result in the avoidance of an area by marine mammals. The response to noise is highly variable between species and even within a species, depending on the circumstances. Between species, a response to noise

can be in the form of changes in swimming direction and speed, breathing rate and vocalization (Richardson et al. 1995). Minke whales, for example, are known to approach stationary or slow moving vessels, but will avoid faster moving vessels (Richardson et al. 1995). Humpback whales have been known to respond to boats at distances of at least 0.5 to 1 km and in some cases several kilometres, especially if the boat is approaching the whale (LGL Limited et al. 2000). In other cases, humpback whales have made no attempt to avoid moving ships in an offshore environment.

The use of thrusters by semi-submersible drilling units and drill ships to maintain position is also a source of relatively loud, intermittent noise during offshore exploration drilling activities. Thrusters can produce intense cavitation (air bubble implosion) noise underwater (ANZECC 2000), and recent modelling indicates that they can produce high levels of underwater sound (Lawson et al. 2001, cited in SEICL 2002).

There is very little information available on how seals react to ships or drilling structures in the open ocean. Most of the ship avoidance information on seals has come from studies conducted during ice breaking, which may or may not be relevant in an open ocean setting. Generally, seals seem to be more tolerant to ships than whales. In one study, seals on the ice dove into the water when approached by a boat within 100 to 300 m (Calambokidis et al. 1983). Seals seem to be able to habituate to vessels when the same vessels approach regularly (Bonner 1982).

Dolphins are more likely to approach moving vessels and ride in their wake (Shane et al. 1986). However, dolphins that have experienced boat-based harassment may avoid boats (Richardson et al. 1995). Other toothed whale species, such as orcas, generally avoid boats (LGL Limited et al. 2000).

Low-flying aircraft elicit diving behaviour in many marine mammal species, especially where the activity is unfamiliar (Richardson et al. 1995). A recent study (Patenaude et al. 2002) found few reactions to overflights of fixed-wing aircraft at altitudes of 60 to 460 m, mostly when lower than 180 m. They found more behavioural responses to helicopters, mostly when the helicopter was within 250 m laterally and at less than 150 m altitude. Minke whales have responded to helicopters at an altitude of 230 m by changing course or slowly diving (Leatherwood et al. 1982). Low-flying aircraft may also cause seals to dive. The effect is temporary in that the helicopter passes or the mammal will move if the helicopter is stationary, during refuelling, for example.

5.3.1.3 Drilling Activities

Drilling units emit some noise continuously during operation, while other noises are intermittent during different stages of drilling. Detailed studies of effects on cetaceans of noises produced in association with offshore drilling are lacking. Most available analyses have been based on known intensities of sounds produced, the modelled or observed attenuation of such sounds, and the hitherto limited literature

on responses of marine mammals to sounds of various pitches and intensities (e.g., Richardson et al. 1995).

Marine mammals are more tolerant of stationary sources of noise than moving sources. This seems especially true for seals, which will approach a stationary vessel or fixed platform (LGL Limited et al. 2000). Dolphins and other toothed whales have also reportedly approached offshore drilling platforms (Richardson et al. 1995). On the Grand Banks, humpbacks have been observed breaching and feeding within a few hundred metres of the Hibernia platform. Cetaceans have been known to approach rigs elsewhere (Richardson et al. 1995), including SOEI production wells (Hurley 2000).

The most likely effect from a drilling project on marine mammals is temporary avoidance of a particular area due to noise. The spatial extent of any such avoidance for most species will likely be approximately 0.5 to 1 km. Whales known to exhibit long distance avoidance, such as Northern Atlantic right whale, may also occur in the study area. Avoidance behaviour by the most common species in the area can be expected 0.5 to 1 km from an approaching vessel. The degree of marine mammal avoidance from a stationary drilling unit will depend on the type of drilling unit used. Avoidance from a drill rig is expected to be limited beyond 100 m, whereas avoidance from a drill ship may range from 1 to 10 km (LGL Limited et al. 2000). Malme et al. (1985) reported that humpbacks exhibited no avoidance when exposed to simulated drill ship, semi-submersible, drill platform, and production platform noises. Under typical ambient noise conditions, low-frequency noise from a drilling platform might be detectable no more than 2 km away near a shelf break (Richardson et al. 1995). Stationary offshore drilling activities appear to have less effect on cetacean behaviour than do moving sound sources such as aircraft and ships (Richardson et al. 1995).

The effect of such noise on marine mammals is considered highly reversible; once the source is removed, mammals are expected to return to the area (Davis et al. 1987).

5.3.1.4 Wellhead Removal

Upon completion of a drilling program, wells are typically abandoned. Operators would likely attempt to remove wellheads by mechanical means, in which the well is plugged and the well casing is cut and removed just below the surface of the seafloor. An ROV is then used to inspect the seabed. There is typically little interaction with marine mammals and sea turtles during the mechanical separation and recovery of wellheads.

However, the uses of explosives to remove wellheads may affect marine mammals and sea turtles. Reported responses have ranged from observed avoidance by some species to considerable tolerance by others (Richardson et al. 1995). Overall little is known about the effects of high-amplitude rapid-onset acoustic signals on the behaviour of marine mammals (Todd et al. 1996). The noise generated by underwater explosions can also kill or injure marine mammals (Trasky 1976; Ketten et al. 1993; Ketten

1995; Morton and Symonds 2002), with gas-containing organs (such as the lungs and intestines) and the auditory system being particularly susceptible (MMS 2001a). Few data exist on disturbance or injury effects to marine mammals from underwater blasting. Threshold levels for injury or death have not been established.

Fitch and Young (1948) reported that grey whales were apparently unaffected by 9 to 36 kg charges used for seismic exploration, while Gilmore (1978) noted that grey whale migration was sometimes interrupted by similar underwater blasts within a few kilometres of the migration corridor. Bottlenose dolphins observed at 594 m (1,950 feet) away from a platform removed by explosives in 1986 swam rapidly away at detonation. They were reportedly exposed to a calculated peak of 213 dB re: 1 μ Pa at 1,200 to 1,800 feet (Klima et al. 1988). Humpback whales within 2 km of subbottom explosions (200 to 2,000 kg) in Bull Arm, Newfoundland, showed no detectable behavioural responses (Lien et al. 1993; Todd et al. 1996), but at least two whales in the area were injured and may have been killed by the blast (Ketten 1993). A study of auditory and behavioural responses of bottlenose dolphins and a beluga whale to impulsive sounds resembling distant underwater exposures found that a disruption in behaviours began to occur at exposures corresponding to 5 kg charges at 9.3 km and 5 kg at 1.5 km for the dolphins and 500 kg at 1.9 km for the beluga whale (Finneran et al. 2000).

A recent study in the North Sea (Nedwell et al. 2001) concluded that, assuming humans and cetaceans have an equivalent dynamic range of hearing, a 45-kg confined blast could result in a measurable risk of irreversible hearing damage up to 600 m from a blast. The same study also concluded that the same level of explosion could produce a low level of blast injuries (and no ruptured ear drums) up to 2.2 km from the blast.

The potential for damage to sea turtles from the explosive removal of offshore structures first became apparent in early 1986 when 51 dead sea turtles washed ashore on Texas beaches after 22 underwater explosions (CTRFOS 1996). An experiment found that all four turtles placed in cages within 365 m (1,200 feet) of four 23-kg (50-lb) explosions to remove a platform in 9 m (30 feet) of water were rendered unconscious, while turtles placed at 915 m (3,000 feet) also experienced short-term health effects (Klima et al. 1988). Other incidences of sea turtle injury and mortality following the explosive removal of subsea structures have also been reported (e.g., O'Keeffe and Young 1984; Gitschlag and Renaud 1989). Overall there is limited information available on turtle mortality as they can be difficult to see, and because turtles killed by explosions may not float to the surface for several days (NRC 1990). Also, non-lethal or delayed effects may not be apparent to observers (CTRFOS 1996).

Young (1991) calculated safe distances for several marine animals from underwater explosions of various sizes. These calculations were for open water blasts, and did not account for the dampening effects that would occur if the charge were detonated below the seafloor. For an approximately 23-kg (50-lb) charge, the estimated safety distances were 530 m for odontocetes and 300 m for baleen whales.

The Minerals Management Service (MMS) has established specific measures to be taken to protect marine mammals and sea turtles during the removal of subsea structures using explosives (MMS 2001b). These guidelines specify that the detonation of underwater explosives be delayed until observed marine mammals and/or sea turtles are more than 914 m (1,000 yards) away from the blast site. The guidelines also require monitoring of the blast site and adjacent area before, during, and after the detonation of charges by trained observers (see Section 5.3.2.2.2).

Given the potential environmental effects associated with these underwater explosions, operators are encouraged to ensure that the design of wells and casings will facilitate the effective mechanical cutting and removal of the wellhead.

5.3.1.5 Potential Food Contamination

Waste Water Discharge

Marine mammals can be affected by wastewater discharge through effects on water quality or biota (i.e., food sources). Deck drainage is sent through an oil-water separator before discharge. During well testing, small amounts of produced water may be released after treatment. All discharges from an offshore drilling platform are subject to the OWTG (NEB et al. 2002). The contents and volume of wastewater from sinks, showers and laundry will not contain harmful contaminants. Sanitary and food waste will be quickly broken down. Marine birds, plankton, fish, benthic invertebrates and bacteria all contribute to the biodegradation of organics offshore. Given the nature and volume of such discharges in an open ocean environment, they pose little risk to marine mammals and sea turtles.

Drill Mud and Cuttings Discharge

The degree to which drill muds and cuttings can interact with marine mammals and sea turtles is limited to the degree that their food supply is affected. The benthic food sources of some toothed whales may be affected by drill mud and cuttings discharges. The baleen whales (i.e., minke and humpback) feed from the water column on plankton and on small schooling fish, such as capelin. Toothed whales (dolphins and orcas) feed from the water column as well, mostly on fish and squid. Seals are known to feed on fish from the water column as well as from benthic habitats; however, bottom feeding by seals will not likely occur in the deeper areas. Turtles feed primarily on jellyfish. Pelagic food sources will not likely be measurably affected by drilling muds and cuttings.

Although the quality and dispersal of discharged cuttings will be very site-dependent, experience to date on the Scotian Shelf indicates that any potentially negative effects will be very local at most (Hurley 2000).

5.3.1.6 Accidental Events

Marine mammals and sea turtles can be affected by an oil spill if they come in direct contact with oil. Dermal lesions and eye irritation are likely to occur with prolonged contact. Respiratory tract and digestive tract irritation will occur if oil is ingested through breathing or eating. Oil does not affect the ability to maintain body temperature, except for young seal pups.

Most marine mammals can withstand some oiling without toxic or hypothermic effects, and impairment of more sensitive areas like eyes and nasal passages are likely to be avoided if animals experience discomfort and move away before being affected (Geraci and St. Aubin 1990). The same effects and response are likely to occur in sea turtles. If a blowout releases gas and light condensates rather than heavy oils, any effects are likely to be much more limited in time and extent.

Mammals are able to digest and excrete oil, so it will not accumulate if exposure is limited. No long-term effects on marine mammals from external exposure, ingestion or bioaccumulation have ever been demonstrated from an oil spill (LGL Limited et al. 2000).

As summarized by McLaren (1990), the discharge of large amounts oil into ice fields may pose special problems for sea mammals that are obliged to surface for breathing in patches of open water that have amassed higher concentrations of oil at temperatures at which evaporation may be reduced.

It is not known whether sea turtles are able to avoid an oil spill, but most marine mammals have been observed avoiding or attempting to avoid spills. Direct exposure to oil should therefore be brief, if it occurs at all. Temporary exposure through feeding on oiled prey may occur.

5.3.1.7 Summary

A summary of the activities likely to occur in association with seismic surveys and exploration drilling programs in the Laurentian Subbasin and potential interactions with marine mammals and sea turtles is provided in Table 5.8. The table also provides examples of general mitigation measures which may be implemented to avoid or reduce any adverse effects on marine mammals and sea turtles, as well as a number of compliance standards which may apply to such activities. Table 5.8 is not intended to be comprehensive or prescriptive, but rather provides a general summary of typical interactions and mitigation at a level of detail appropriate for an SEA. Project-specific effects vary depending on the nature, location and timing of individual projects and activities, and mitigation measures will be determined by the C-NOPB and C-NSOPB in assessing specific seismic surveys and exploration drilling programs.

Table 5.8 Potential Environmental Interactions and Mitigation Summary – Marine Mammals and Sea Turtles

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
SEISMIC SURVEYS		
Air Gun Operations	avoidance, attraction, interference with vocal communication, injury	- minimization of airgun source level to minimum practical for survey - use of "soft-start" procedures
Vessel Traffic	attraction, disturbance	minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
DRILLING		
Planned Activities		
Vessel Traffic	attraction, disturbance	- minimization of traffic volume - use of existing and common travel routes where possible - minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
Aircraft Traffic	disturbance	avoid overflights at low altitudes
Over-the-side Discharges		
- Sewage, Deck Drainage, Bilge/Cooling Water, Wash Fluids	- effects on marine mammal and sea turtle health - effects on food sources	- treatment of discharges (OWTG) - screening of chemicals through OCSG - oil water separator to treat contained deck drainage, collected oil shipped to shore - on-shore disposal of solid and hazardous wastes
- Drill Cuttings	- effects on marine mammal and sea turtle health - effects on food sources	- use of WBMs where possible - treatment to compliance with 2002 OWTG - chemical screening and selection
Discharges at Depth		
- Drilling Mud (WBMs)	effects on food sources	- compliance with 2002 OWTG - chemical screening and selection
- Drill Cuttings	effects on food sources	
Atmospheric Emissions (Exhaust, Gas Venting/Flaring)	n/a	
Well Testing	- effects on marine mammal and sea turtle health - effects on food sources	- compliance with 2002 OWTG - atomize produced water with hydrocarbons in the flare
Well Abandonment		
- Mechanical Separation	n/a	
- Chemical Explosives	effects of blasting (if required)	- use of mechanical separation where possible - design of well and casings to ensure effective mechanical cutting and recovery - scheduling of blasting - marine mammal surveillance; delay of detonation until observed marine mammals are out of the area - setting charges below the sediment surface - minimize amount of explosives used - use of high velocity explosives - minimize number of consecutive blasts per group of detonations - staggering of individual blasts
Unplanned Events		
Fuel/Oil Spill (surface and subsurface)	effects on marine mammal and sea turtle health	- oil spill prevention and preparedness - oil spill response plan

Environmental compliance monitoring (including reporting on waste discharges, emissions, and treatment systems) is required to verify adherence to applicable legislation and any conditions of regulatory approval.

5.3.2 Environmental Planning and Management Considerations

5.3.2.1 Occurrence and Spatial and Temporal Trends

As discussed in Section 3.2.5, 18 species of whales and dolphins are known or likely to occur in the Laurentian Subbasin. The deep channel extending to the shelf break and the channel banks clearly provide a mix of habitats which are known to be used by cetacean populations elsewhere in the western North Atlantic. Four species of phocid seals are also known or expected to occur in the area, and two species of sea turtles may occur in the region in summer. Of these species of marine mammals and sea turtles, most have designations by COSEWIC and/or under the United States *Endangered Species Act*. Potential effects to marine mammals and sea turtles are therefore an important consideration in planning and undertaking seismic surveys and drilling programs in the Laurentian Subbasin.

An overview summary of the likely occurrence, timing and habitats of marine mammals and sea turtles in the Laurentian Subbasin was provided in Sections 3.2.5 and 3.2.6. As indicated, probable cetacean occurrence within the study area varies from relatively common (e.g., minke whale, white-sided dolphin) to very rare (e.g., beluga whale, bottlenose dolphin). Although whales and dolphins can occur throughout the area, with a number occurring most frequently along the banks (e.g., the minke whale), the Laurentian Channel and its adjacent slopes are the habitats which are probably the most used by whales and dolphins overall in the study area. The timing of occurrence also differs considerably among species, with some probably occurring as year-round residents (e.g., sperm whales), others occurring primarily during the summer months (e.g., sei whale), and others primarily as spring-fall migrants (e.g., minke and fin whales). Of the four seal species which are known or likely to occur in the region, the grey seal is likely the most common, and occurs primarily in summer. The endangered leatherback turtles is known to occur in the Laurentian Subbasin in summer, with other species predicted to occur much more rarely.

5.3.2.2 Mitigation of Effects

Given the lack of direct, detailed information on marine mammal and sea turtle populations in the study area at present, only broad generalizations regarding their potential occurrence and distribution can be made at this time. As indicated above, marine mammals and/or sea turtles may be found in the region at any time of the year, and occur throughout the study area.

A number of examples of general mitigative measures which are often implemented in order to avoid or minimize potential effects on marine mammals and sea turtles are provided in Table 5.8. For exploration

drilling programs, for example, these range from standard procedures such as the treatment of drilling discharges to comply with applicable guidelines, to operational planning measures such as the use of common routes by supply vessels and the minimization of vessel traffic.

Given the potential for marine mammals and sea turtles to occur throughout the region at various times of the year, the scientific and social importance of these species, the designation of most species under endangered species legislation, and the limited existing, available information on specific distributions, special care will be exercised in the review of seismic surveys or exploratory drilling programs proposed for the Laurentian Subbasin. As noted previously, potential effects to marine mammals and sea turtles as a result of offshore structures and activities relate primarily to noise. Additional measures to avoid or reduce potential effects during seismic surveys could potentially include:

- depending on the level of activity proposed, the timing and location of proposed seismic surveys, and the presence of any known sensitive species or areas, measurements of background sound levels, as well as possible acoustical modelling and/or monitoring of the proposed airgun arrays, as necessary; and
- the implementation of marine mammal/sea turtle surveillance during seismic surveys, with survey activity not commencing if animals are observed within a specified distance of the source.

In the United Kingdom, for example, the *Guidelines for Minimising Acoustic Disturbance to Marine Mammals from Seismic Surveys* (JNCC 1998) outline specific measures to reduce potential effects to marine mammals as a result of seismic surveys. The guidelines outline the following steps to be taken before and during offshore seismic activity, including:

- trained observers will check for any marine mammals within 500 m, at least 30 minutes before commencement of any use of the seismic sources;
- if marine mammals are present, the start of the seismic sources will be delayed until they have moved away, allowing adequate time after the last sighting (at least 20 minutes) for the animals to move well out of range;
- even if no marine mammals have been seen, power will be built up slowly from a low energy start-up (e.g., starting with the smallest air-gun in the array and gradually adding in others) over at least 20 minutes to give adequate time for marine mammals to leave the vicinity; and
- throughout the survey, the lowest practicable power levels will be used.

Severe wind and wave conditions may result in difficult sighting conditions for marine mammals during seismic surveys. The guidelines also note that hydrophones and other listening equipment may provide additional information on the presence of inconspicuous species or individuals (e.g., submerged animals), particularly during periods of poor weather (JNCC 1998).

The current Joint Nature Conservation Committee (JNCC) guidelines specify that if marine mammals are present, the start of the seismic sources should be delayed until they have moved away. Where practical, shutting down the airguns if marine mammals are sighted within a certain distance of the seismic vessel may also be considered, where possible and as necessary (e.g., depending on the species involved, the number of individuals sighted, and if the observed animals do not appear to be moving away).

The JNCC guidelines regarding marine mammals monitoring during seismic surveys are currently undergoing review and revision (JNCC 2002), although revised guidelines have not yet been issued.

Where the removal of subsea structures using explosives is required, any such detonations should be planned to avoid potential interactions with these species. As discussed previously, the MMS, for example, has outlined specific measures to be taken to protect marine mammals and sea turtles during the removal of subsea structures using explosives (MMS 2001b), which include the following:

- monitoring of the site before, during, and after the detonation of charges by trained observers;
- delaying the detonation of underwater explosives until observed marine mammals and/or sea turtles are more than 1,000 yards (914 m) away from the blast site;
- staggering blasts, and avoiding the use of scare charges;
- limiting blasts to daylight hours (between one hour after sunrise and one hour before sunset);
- instructing all personnel who dive during the course of removal operations to scan the subsurface areas around the removal site for the presence/absence of sea turtles and marine mammals; and
- conducting a post-detonation survey (could include visual observations from the surface, as well as during the post-removal ROV survey), and submission of a post-removal report.

Again, given the potential environmental effects associated with these underwater explosions, operators are encouraged to ensure that the design of wells and casings will facilitate the effective mechanical cutting and removal of the wellhead.

Training programs for observers conducting marine mammal surveillance and surveys during offshore activities are available through DFO and other organizations.

5.3.2.3 Information Availability and Requirements

Although existing information will be of use in planning specific seismic surveys and drilling programs in the study area, overall, there is a relative lack of information on marine mammals and sea turtles in the Laurentian Subbasin.

As discussed previously, in some cases operators have undertaken operational monitoring programs for marine birds during offshore exploration programs. In conjunction with any such avifauna observations, monitoring of marine mammals and sea turtles could also be considered. Observations from exploration rigs and vessels operating in the area would, over time, contribute to the overall knowledge base regarding the presence, abundance and spatial and temporal distribution of marine mammals and sea turtles in the Laurentian Subbasin.

In addition, a database of cetacean sightings currently under development by DFO will add considerably to existing knowledge regarding marine mammals in the study area. The database contains nearly 13,000 sightings from over the past 20 years, including data for the Laurentian Subbasin. Although this information is unavailable at the time of writing, it will represent an important source of information for planning and assessing seismic surveys and drilling programs in the Laurentian Subbasin.

There is also an ESRF-funded study ongoing in the Gully area, looking at the effects of seismic activities with northern bottlenose whales. The results from this study should provide additional information regarding behavioural effects of seismic activities and important information on acoustic modelling for this area.

Given the considerable scientific and stakeholder interest in these species, other government and industry-funded research programs may consider focussing on marine mammals and sea turtles in the general region in the future (e.g., those conducted through ESRF, PERD, or PRAC). The collection of additional information (through, for example, ship board surveys of the general area) would eventually contribute to the overall knowledge base regarding marine mammal and sea turtle presence and distributions in the region over the long-term.

5.3.3 Cumulative Environmental Effects

As noted previously, the specific nature and spatial and temporal distribution of potential exploration activity in the Laurentian Subbasin is not currently known, although a number of assumptions have been made for the purposes of the SEA. At this point, best estimates indicate that there may be a total of eight to ten wells drilled in the area, with a maximum of two wells drilled at any one time (one in shallow water and one in a deeper part of the area). It is anticipated that approximately 2 to 3 seismic surveys may be conducted annually over the next few years in the region.

The potential effects of oil and gas exploration structures and activities on marine mammals and sea turtles relate primarily to noise. As a result of the existing marine activities in the study area (e.g., fishing vessels, general marine traffic) and naturally occurring underwater noise, the region's underwater environment is currently quite noisy. The additional noise created as a result of seismic surveys and drilling programs will add to underwater noise levels in the Laurentian Subbasin.

Based on studies in other areas, most potential effects to marine mammals as a result of seismic surveys and drilling programs occur primarily within relatively close proximity to the sources of noise. The anticipated level of exploration in the region and the likely spatial and temporal distribution of potential drilling projects will limit the potential for interaction between the effects of these relatively isolated and intermittent sources of noise. Seismic activities would likely be conducted sequentially rather than concurrently. Again, the often spatially-extensive nature of these surveys (especially in the case of 2D surveys), increases the potential for interactions between the effects of individual programs. In addition, good sound propagation is likely in portions of the Laurentian Subbasin (especially the deeper channel areas). The widespread and migratory nature of these species also increases the potential for cumulative environmental effects to occur.

Avoidance of an area by marine mammals as a result of a single seismic survey or drilling program may be temporary, but an area may not be reoccupied if intense activity continues over the long-term in an area. Therefore, the potential for cumulative effects on marine mammals and sea turtles will depend on the eventual intensity and spatial distribution of such activities. Again, consideration of cumulative environmental effects will be a part of regulatory planning and decision-making regarding offshore exploration in the Laurentian Subbasin. This will minimize the potential for spatial and temporal interaction between individual seismic surveys and/or drilling programs in the area and their effects, and thus, minimize the potential for cumulative effects.

In addition to the potential effects of noise, marine mammals and sea turtles may also be affected by other disturbances which may be associated with other types of activities in the marine environment, including general vessel traffic and commercial fishing activity. Major threats to marine mammals throughout their ranges are quantitatively estimated species-by-species to some extent by NMFS (2002b). These are entrapment (especially smaller species) and entanglement (especially larger species) in fishing gear, and collisions with ships (especially larger species). Although pollution and other environmental effects are often mentioned as potential threats to marine mammals, they are not assessed quantitatively by NMFS (2002b).

5.4 Fisheries

The environmental effects analysis for fisheries focuses on Canadian commercial fishing activity in the study area, but also includes consideration of experimental and exploratory fisheries. Since St. Pierre and Miquelon fisheries closely parallel key fisheries for Canada, potential effects on St. Pierre and Miquelon catches can be expected to mirror those on Canadian catches. Nearshore recreational fisheries are unlikely to be affected by exploration in the study area, and are therefore not directly included as part of this assessment.

5.4.1 Potential Interactions and Existing Knowledge

Most of the information available on potential interactions between the fishing industry and the offshore oil and gas industry has been gathered through stakeholder consultations undertaken as part of recent environmental assessments for petroleum exploration and development projects in Atlantic Canada and elsewhere. These consultations have identified loss of access, damage to gear, reduced fish catches, biophysical effects on fish (including real or perceived tainting) and subsequent reductions in fish landings and value, and oil spills as the primary issues of concern. DFO has also raised concerns regarding potential interactions with research vessel activity.

Fishers elsewhere in the world have expressed similar concerns with respect to offshore oil exploration and development. A recent report (Lam 2001) provides a good review of fisheries-related in the United Kingdom over more than three decades of offshore oil and gas development. Issues and concerns include loss of access, damage to gear and compensation for damage, reef (biophysical) effects around pipelines and suspended wellheads, and communication between the two industries with respect to potential hazards. Similarly, issues identified off California (MMS 2001a) have included space use conflicts, seafloor debris and reduced catch due to seismic activity. Numerous other such reports exist, all of which highlight the importance of communication between the fishing and oil industry, often through the establishment of formal liaison mechanisms to deal with specific issues.

Based on the information presented above, the following potential interactions are the key issues addressed in this analysis:

- loss of access;
- damage to fishing gear or vessels;
- reduced fish catches;
- indirect effects due to biophysical effects on fish (including taint); and
- oil spills.

Potential benefits from increased information, communication and emergency response capabilities are also considered.

5.4.1.1 Loss of Access

Loss of access to fishing grounds can occur when safety zones are established around exploratory drilling operations (Section 2.2.2.3). The magnitude of any such effects would relate to the number of operations in the area. Typically, no-fishing zones established around drilling operations are relatively small (in the range of 0.5 km²). However, for certain fisheries that use longline gear (up to 70 km), the exclusion zone would have to be larger to ensure that the gear did not drift into drilling rigs (LGL Limited et al. 2000). In 2001, there were 1,175 longline fishing sets in the general vicinity of the study area (i.e., NAFO Unit Areas 3Psf, 3Psg, 3Psh, 4Vn, 4Vsb and 4Vsc).

The frequency of fishing trips and the often extensive spatial and temporal distribution of fishing activity in the region increases the probability of interactions. Although the specific intensity, location and timing of potential drilling activities in the study area are not known at present, fisheries that would likely be most sensitive to no-fishing zones and interactions with vessels include:

- cod, snow crab, Iceland scallop, redfish, Atlantic halibut and skate fisheries in the Laurentian Subbasin;
- cod, crab, Iceland scallop, American plaice, swordfish, Atlantic halibut, redfish, and shrimp fisheries located along potential traffic routes;
- experimental fishing for sea cucumber and exploratory fishing for crab; and
- DFO research surveys.

5.4.1.2 Damage to Gear

Damage to fishing gear or vessels can result from physical contact with seismic vessels, drill rigs, or equipment and vessels supporting oil and gas exploration. Small spills (less than 50 barrels) and materials lost from vessels or drill rigs can also damage or foul gear. In addition to fishing vessel damage or loss of gear, further economic loss might result from reduced catch following damage.

Given the fisheries in the area, damage would be most likely to occur to gear or vessels fishing for cod, snow crab, Iceland scallop, redfish, Atlantic halibut and skate (Section 3.3.1). However, any such damages are expected to occur infrequently, if at all. As of 2000, there had been no reported damages as a result of the Hibernia and Terra Nova operations on the Grand Banks of Newfoundland (Husky Oil 2000). The C-NOPB reports that on average, there are approximately two fishing gear conflicts per year from seismic activity in the Newfoundland and Labrador Offshore Area (J. McIntyre, pers. comm.).

5.4.1.3 Reduced Fish Catches

The potential effects of seismic surveys on fisheries catches are also typically a concern (see references quoted above). An overview discussion of existing knowledge regarding the potential effects of seismic surveys on fish behaviour, and subsequent effects on fish catches, was provided in Section 5.1.1.1. Given the distribution of fisheries in the study area, the most likely fisheries that may be affected by seismic survey operations include cod, witch, skate, monkfish, sea scallop, and Iceland scallop, as well as high cash species like snow crab and Atlantic halibut. Of these, only cod and monkfish have swimbladders. Any potential effects on catch rates due to seismic survey operations may also compromise the accuracy of information gathered through DFO fish surveys, and thus, its utility for fisheries management.

5.4.1.4 Biophysical Effects on Fish

Biophysical effects to fish and fish habitat as a result of offshore seismic surveys and drilling programs could result in a subsequent loss of fish catch or catch value. Potential effects on fish, including behavioural effects, fish health, taint, toxicity and bioaccumulation and smothering are discussed in detail in Section 5.1. Even where there is a low potential for biophysical effects, perceived effects by the public can affect economic returns from the fishery. However, the latter is much more likely to occur after a large oil spill than as a result of routine activities.

5.4.1.5 Oil Spills (Greater Than 50 Barrels)

Although economic losses are highly site-specific, the most serious effects from major spills have typically been loss of market or market value, loss of access to fishing grounds, damage to fishing gear and fish tainting. Fish mortality as a result of oil spills, although it does occur, is usually not the most critical effect of oil spills on fisheries (see Section 5.1.1, as well as Baker et al. (1991); DeBlois et al. (1997); and LGL Limited et al. (2000) for additional reviews of potential biological effects on fish).

Perceived fish taint has had negative effects on economic returns from fisheries. Areas around oil spills and blowouts have been closed without any evidence of taint. For example, a no-fishing zone was established around the Uniacke wellsite near Sable Island during the blowout of 1984. Taste tests on cod, halibut and haddock caught in the area did not indicate taint (Zitko et al. 1984). Similarly, inspection officers rejected lobster with any trace of external oil and no proof of internal contamination during the Kurdistan oil spill (Tidmarsh et al. 1986). Shellfish prices and sales declined dramatically after the Torrey Canyon spill, even though much of the shellfish catch was from other waters (LGL Limited et al. 2000).

Fish species which are fished in the Laurentian Subbasin are listed in Section 3.3.1. Since 1995, a total of 21 species have been fished in the study area. In general, a number of fisheries that have been relatively lucrative in recent years have distributions that overlap the study area. All fisheries listed in Table 3.16 should be considered as being at high risk for effects in the event of an accidental oil spill.

5.4.1.6 Communication and Emergency Response Capabilities

Overall, the fishing industry would likely benefit from increased communications and emergency response capabilities as a result of offshore exploration in the study area.

5.4.1.7 Summary

A summary of the activities likely to occur in association with seismic surveys and exploration drilling programs in the Laurentian Subbasin and potential interactions with commercial fisheries is provided in Table 5.9. The table also provides examples of general mitigation measures which may be implemented to avoid or reduce any adverse effects on fishing activity, as well as a number of compliance standards which may apply to such activities. Again, project-specific effects vary depending on the nature, location and timing of individual projects and activities, and mitigation measures will be determined by the C-NOPB and C-NSOPB and the operators in assessing and planning specific seismic surveys and exploration drilling programs.

Table 5.9 Potential Environmental Interactions and Mitigation Summary – Fisheries

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
SEISMIC SURVEYS		
Air Gun Operations	- behavioural / biophysical effects on fish - reduction in fish catches	- minimization of airgun source levels - use of "soft-start" procedures
Vessel Traffic	- temporary loss of access to fishing grounds - damage to fishing gear and vessels - increased communication - biophysical effects on fish	- where possible, coordinate activities with the fishing industry to reduce conflict/interaction with fishing activity during peak fishing times - discussion and communication with fishing industry - notification to mariners in a timely manner - compensation for gear damage - minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
DRILLING		
Planned Activities		
Vessel Traffic	- temporary loss of access to fishing grounds - damage to fishing gear and vessels - increased communication - biophysical effects on fish	- discussion and communication with fishing industry - common traffic routes with other vessels, where practical - notification to mariners in a timely manner - compensation for gear damage - minimize discharges; compliance with the <i>Canada Shipping Act</i> and other relevant regulations
Aircraft Traffic	n/a	
Safety Zone / Presence of Structures	temporary loss of access to fishing grounds	- discussion and communication with fishing industry - small, temporary zone; minimum 500-m radius

Components / Activities	Potential Environmental Interactions	General Mitigation Measures and Applicable Compliance Standards
Drilling / Discharges	- temporary loss of access to fishing grounds - damage to fishing gear and vessels - increased communication - biophysical effects on fish	- sequential approach to drilling (if multiple wells) - compliance with 2002 OWTG - chemical screening and selection
Atmospheric Emissions (Exhaust, Gas Venting/Flaring)	n/a	
Well Testing	- damage to gear and vessels - effects on fish	- atomize produced water with hydrocarbons in the flare - compliance with 2002 OWTG
Well Abandonment	- loss of access to fishing grounds - damage to gear and vessels (if wellheads left in place) - effects on fish species (if blasting is required)	- discussion and communication with fishing industry - notifications to mariners in a timely manner - use of mechanical separation where possible - design of well and casings to ensure effective mechanical cutting and recovery - scheduling of blasting - setting charges below the sediment surface - minimize amount of explosives used - use of high velocity explosives - minimize number of consecutive blasts per group of detonations - staggering of individual blasts
Unplanned Events		
Fuel/Oil Spills* (surface and sub-surface)	- temporary loss of access to fishing grounds - damage to gear and vessels - loss of market or market value - increased safety and communication	- design and prevention - oil spill preparedness and response - compensation for damage
* Note: Effects of oil spills on fishing gear and loss of access can often be remedied relatively quickly. However, loss of market and market value and the duration of any such effects depends on media coverage and public perception of fish taint.		

5.4.2 Environmental Planning and Management Considerations

Based on the nature of the fishery in the region in recent years, and existing knowledge regarding potential interactions between seismic surveys and drilling programs and fishing activity, the following sections summarize a number of key planning and management considerations which may help to avoid or reduce potential effects as a result of exploration in the Laurentian Subbasin.

5.4.2.1 Fisheries, Areas and Times

Where possible, seismic surveys are to be planned to coordinate program activities with the fishing industry, to reduce potential conflict with commercial fishing activity during peak fishing times. As indicated in Section 3.3.1, a wide range of fisheries occur throughout the Laurentian Subbasin at various times of the year, and the region is characterized by a complex spatial and temporal pattern of fisheries. This, along with the rather dynamic nature of the fishery, makes it somewhat difficult to generalize about specific locations which may be more sensitive than others. However, based on the information

provided in Section 3.3.1, number of key trends and considerations can be identified to help guide any future planning related to seismic surveys in the region, including:

- Fisheries in the Laurentian Subbasin with the highest landed values in recent years have been those for cod and snow crab. A number of other fisheries, including those for Iceland scallop, redfish and Atlantic halibut, have also had relatively high landed values in recent years.
- Most fishing in the study area (considering both fishing effort and landed value) takes place in the fall (October to December) period, but fishing does occur in all seasons. Based on fishing effort and the value of landings, some of the major fisheries in the Laurentian Subbasin by season include:
 - redfish, cod and Atlantic halibut fisheries from January to March;
 - snow crab, cod, Atlantic halibut, skate and Iceland scallop fisheries from April to June;
 - cod, snow crab and Iceland scallop fisheries from July to September; and
 - cod, snow crab and redfish fisheries from October to December.
- Based on the spatial distribution of commercial fishing activity in the study area in recent years, the following general trends are evident:
 - in winter (January to March), fishing activity has been concentrated primarily along the shelf in the southern portion of the study area, as well as to the northwest within the Laurentian Channel;
 - in spring (April to June), fishing has occurred primarily along the shelf in the southeastern portion of the study area, as well as over the St. Pierre Bank and Halibut Channel and along the bank slope. Fishing activity in the northeastern corner of the study area is of particular significance in terms of landed value (primarily for snow crab);
 - in summer (July to September), fishing activity is relatively more dispersed throughout the region, with fishing occurring on the St. Pierre Bank and Halibut Channel, along the shelf area, and along the slopes and within the Laurentian Channel. Again, fisheries in the northeastern portion of the study area are especially lucrative (mostly crab);
 - in the fall period (October to December), considerable fishing activity occurs along the shelf in the southern part of the study area, as well as throughout the eastern portion of the area over the St. Pierre Bank and slope. Relatively lucrative fisheries (including those for cod, crab and other species) occur in the northeastern and east-central parts of the study area.
- The highest vessel densities for fixed gear fisheries occur from April to June on the southern edge of the St. Pierre Bank, off the Burin Peninsula and in Fortune and Placentia Bay; and from July to September around Cape Breton Island and the middle Nova Scotia Shelf. The most intensive fishing activity with mobile gear occurs from April to June off the Nova Scotia Shelf and mostly in the Banquereau area.

- DFO undertakes fisheries surveys in spring and fall (Newfoundland Region) and spring and summer (Maritimes Region) to assess fisheries stock status.

Detailed information on fishing activity in and around the Laurentian Subbasin is provided in the maps and tables included in Section 3.3.1 and in Appendix C.

5.4.2.2 Consultation and Management

Consultation and communication between operators, regulators and the fishing industry in planning for and executing seismic surveys and drilling programs is by far the most important mechanism for mitigating potential interactions between offshore exploration and fishing activity. Locally, notices to mariners and Fisheries Liaison Observers (FLOs) have been the primary mechanisms for communication with the fishing industry. As of this year, an independent inter-industry organization called One Ocean has been established to facilitate communication and a cooperative relationship between the fishing and petroleum sectors in Newfoundland and Labrador. In Nova Scotia, the Canada-Nova Scotia Fisheries and Environmental Advisory Committee (FEAC) is a multi-stakeholder organization which includes representatives from various government departments and agencies, the fishing industry, environmental groups, aboriginal groups and other organizations. The FEAC provides a forum for the exchange of information, and provides information and advice to the C-NSOPB.

Additional mechanisms are also available and have been implemented in other jurisdictions. The United Kingdom Offshore Operators Association (UKOOA), in collaboration with various other agencies, maintains a database containing oil and gas industry information relevant to the fishing industry. Thirty-four oil and gas operators within the United Kingdom sector of the North Sea supply information to the database. These data are then collated and added to data from other sources such as an inventory of suspended wellheads and a list of Safety Zones. This information is then sent to various users. The association also has development software which uses these data to graphically display information to fishers onboard vessels (UKOOA n.d.). These added communications mechanisms could also be considered for the Laurentian Subbasin in the coming years. Information requirements should be assessed through discussion with the fishing industry. Also, in order to avoid and resolve specific conflicts between the fishing industry and exploration operations, program-specific approval processes may include consultations with fishers that are active in the designated exploration area.

The establishment of no-fishing zones around sensitive sub-sea drilling installations and in areas of high vessel traffic minimizes the potential for conflict between the offshore petroleum sector and the fishing industry. This mitigation measure aims to decrease the potential for collisions between fishing gear or vessels and sub-sea structures and vessels involved in offshore exploration. Typically, no-fishing zones for exploratory drilling programs are relatively small (in the range of 0.5 km²). If a series of wells are to be drilled in a given area, a sequential approach to drilling is often used for logistical reasons, which

minimizes the loss of access to fishing grounds. If well heads are to remain in place after the completion of drilling, notices to mariners should be issued warning of potential hazards.

The use of common routes by supply vessels whenever possible can also minimize effects on the fishing industry. Oil and gas industry vessels should also be fully aware of the location of large fishing aggregations. If feasible, supply vessels could then use alternate routes around key fishing grounds, particularly while fishing is at its peak.

FLOs are also an important means of minimizing the potential for conflicts between seismic activities and the fishing industry. The use of FLOs involves the hiring of fishers by seismic operators to help coordinate seismic surveys and fishing activities in test areas. Responsibilities can include communicating with fishing vessels to warn of potential dangers, and proposing alternative routes to the seismic vessel crew away from larger fishing aggregations.

As discussed above, wherever possible, seismic surveys are planned to coordinate program activities with the fishing industry to reduce potential conflict with commercial fishing activity during peak fishing times, and to minimize interaction with DFO survey vessels. Consultation with key fishing organizations and with the Maritime and the Newfoundland Branches of DFO to obtain information on the location and timing of fishing and research activities is an important part of the planning process for specific programs.

With respect to large spills, drilling operators are required to develop plans which outline procedures for preventing and responding to spills. Operators are also expected to demonstrate that a systematic approach to safety management will be in place throughout the program.

5.4.2.3 Compensation

If management measures fail, a variety of measures exist to compensate fishers for the loss of or damages to fishing gear and/or vessels related to offshore petroleum activity (e.g., damage due to interference with seismic streamers or in the event of a spill). These are listed in the C-NOPB and C-NSOPB (2002b) *Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activity*. Briefly, there are three options available to claimants for recovery of loss or damage to fishing gear and/or vessels when this can be attributed to a specific offshore operator:

- i) voluntary settlement by the operator for direct compensation;
- ii) application to the appropriate Board for recovery of damages, from the operator's security deposit;
or
- iii) civil suit through the appropriate court of law.

If more than one operator is active in the study area, there may be some delays in compensation for lost or damaged gear or lost revenue if there is disagreement about which operation is responsible.

Two mechanisms are in place for compensation of damages from a non-attributable nature:

- i) the CAPP's Commercial Fisheries Compensation Program for Loss Resulting from Non-Attributable Gear or Vessel Damage; or the
- ii) Ship-Source Oil Pollution Fund.

5.4.3 Cumulative Environmental Effects

Cumulative effects on commercial fisheries could occur as a result of the combined effects of seismic surveys and drilling activity and general marine traffic within the study area (through direct disturbance, gear damage and/or effects on fish resources).

Specific details on the nature and spatial and temporal distribution of potential seismic surveys and drilling programs in the Laurentian Subbasin are not currently available. As discussed in Section 2.2.3, it is assumed that there would be a total of eight to ten wells drilled in the region during the period of the licences, with no more than two drilling units active at any given time (one in deep water and one in shallow water). It is anticipated that approximately two to three seismic surveys may be conducted annually over the next few years in the region.

Drilling activity at any one site in the study area will be relatively of relatively short-term duration. The establishment of safety zones around drill sites is an important mitigation measure to prevent potential effects, and typically does not interfere greatly with fishing activity, given the relatively small size of these zones. Seismic activities would likely be undertaken sequentially, although the often widespread nature of these surveys increases the potential for interaction with fishing activity and between the effects of individual programs. The potential for interference with fishing activity due to the presence of drill rigs and seismic and supply vessels traffic can be mitigated through communication between the two industries, as well as standard measures such as the issuance of Notices to Mariners. Wherever possible, seismic surveys are to be planned to coordinate program activities with the fishing industry to reduce potential conflict with commercial fishing activity during peak fishing times. In addition, routing supply vessel traffic to avoid the more active fishing aggregations in a region is a practice generally used for activities in the marine environment, with common routes used where possible. Although unlikely, damage to gear or vessels, would be managed through applicable compensation policies and procedures.

5.5 Effects of the Environment on Offshore Exploration

The nature and characteristics of the physical environment are important considerations in the planning and execution of offshore seismic surveys and exploration drilling programs. Severe operating conditions for vessels and helicopters can occur in the Newfoundland and Labrador and Nova Scotia Offshore Areas as a result of wind, wave and ice conditions. Extreme conditions may affect program schedule and operations, including the timing of seismic vessel movements, drilling activity and the provision of supplies and service support to a drilling unit.

Detailed analyses of meteorology and oceanographic conditions are therefore typically part of an operator's overall engineering feasibility and design. Appropriate design and planning based on this information (e.g., in the selection of the drilling rig, vessels and aircraft used) helps to ensure the safety of personnel, equipment, vessels and the natural environment during the execution of seismic surveys and exploration drilling programs in the offshore environment. The deployment and retrieval of seismic equipment, for example, is a time-consuming process and cannot be conducted safely when significant wave heights exceed 3 m (Davis et al. 1998). Meteorological and oceanographic monitoring programs are often implemented to anticipate and respond to severe conditions.

The study area lies within a region that is generally regarded as the most seismically active portion of the Newfoundland Continental Shelf, and a number of significant earthquakes have occurred in the area over the past century. Specific earthquake areas and faults in the study area are reasonably well known. As exploration drilling programs are typically of relatively short-term duration, the probability that significant geological movements will occur during any one program is relatively low. However, the seismically active nature of the general area would be an important planning and design consideration for any future offshore petroleum activity in the Laurentian Subbasin. Risk-based earthquake design is routinely used in engineering and design work for offshore structures in seismo-tectonic environments (see JW 2001). The American Petroleum Institute (API), for example, has a minimum design threshold for seismic events noted in their Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design (API 1993, cited in EnCana 2002).

Icebergs originate from glaciers in Greenland and drift along the Labrador current, usually decaying in the Grand Banks region. Although less common than in other operating areas, icebergs do occasionally enter the study area. In addition, although the area is generally beyond the extent of sea ice from the Gulf of St. Lawrence and offshore Newfoundland, ice can occur in the Laurentian Subbasin. Fog conditions are common in the general area, and can be hazardous for shipping and drilling operations, particularly when ice is present. Monitoring the presence and movements of icebergs is part of routine operational procedures during offshore operations in areas which are subject to seasonal intrusions of ice. Appropriate safety measures can then be taken, including moving the drilling unit if required. Sea ice conditions are also typically monitored where required. Real-time ice data are, for example, available through the Canadian Ice Service (Canadian Ice Service 2003).

The freezing of salt spray results when the air temperature is below -1.8°C , sea temperature is below 6°C and wind speeds are greater than 10 m/s. Freezing precipitation is also an important consideration. Drilling programs can be scheduled year-round with the appropriate vessel and, therefore, superstructure icing of supply vessels and helicopters can be an issue. If such icing is possible, vessels and helicopters would have to have equipment and procedures in place to adequately operate in these conditions.

Depending on the timing and duration of specific programs, the potential effects of the biological environment on exploration drilling activities may also require consideration in planning and undertaking such programs (e.g., biofouling, or the colonization of structures by epibenthic communities, plankton blooms and possible interference with visual inspections of structures).

A general overview of the physical environment of the Laurentian Subbasin area is provided in Section 3.1, based on existing, readily available information. The planning, design and environmental assessment of individual proposed seismic surveys and exploration drilling programs in the region will be based upon the compilation and analysis of detailed information on physical oceanographic conditions in the area to help to ensure the safety of personnel, equipment, vessels and the natural environment.

The *Guidelines Respecting Physical Environmental Programs during Petroleum Drilling and Production Activities on Frontier Lands* (NEB et al. 1994) provide a detailed overview of requirements for the operators of petroleum drilling or production installations regarding the observing, forecasting, and reporting of physical environmental data. The primary objective of these physical environmental monitoring programs is to ensure that appropriate weather, oceanographic, and ice information is available during an exploratory drilling or production program to support the safe and prudent conduct of operations, emergency response, and spill counter-measures (NEB et al. 1994).

6.0 SUMMARY AND CONCLUSION

The C-NOPB and the C-NSOPB intend to negotiate the conversion of the existing federal exploratory permits for their respective offshore areas in the Laurentian Subbasin into exploration licences. As a consequence, exploration drilling (and, if successful, delineation drilling), may be proposed. It is also anticipated that seismic and other geoscientific surveys will be undertaken in the area.

This SEA has been completed in relation to potential offshore oil and gas exploration in the Laurentian Subbasin, including potential seismic surveys and drilling programs. The C-NOPB and C-NSOPB will use the information presented in this SEA in decision-making for offshore exploration activities for the Laurentian Subbasin area.

The SEA provides an overview of the existing environment of the Laurentian Subbasin, discusses in broader terms the potential environmental effects which may be associated with offshore oil and gas exploration in the study area, identifies knowledge and data gaps, highlights any key issues of concern, and makes recommendations for mitigation and planning. Information from the SEA will assist the C-NOPB and C-NSOPB in determining whether exploration rights should be offered in whole or in part for an area, and may also identify general restrictive or mitigative measures that may be considered for application to seismic and/or drilling activities.

The following provides a summary of the results and conclusions of the assessment.

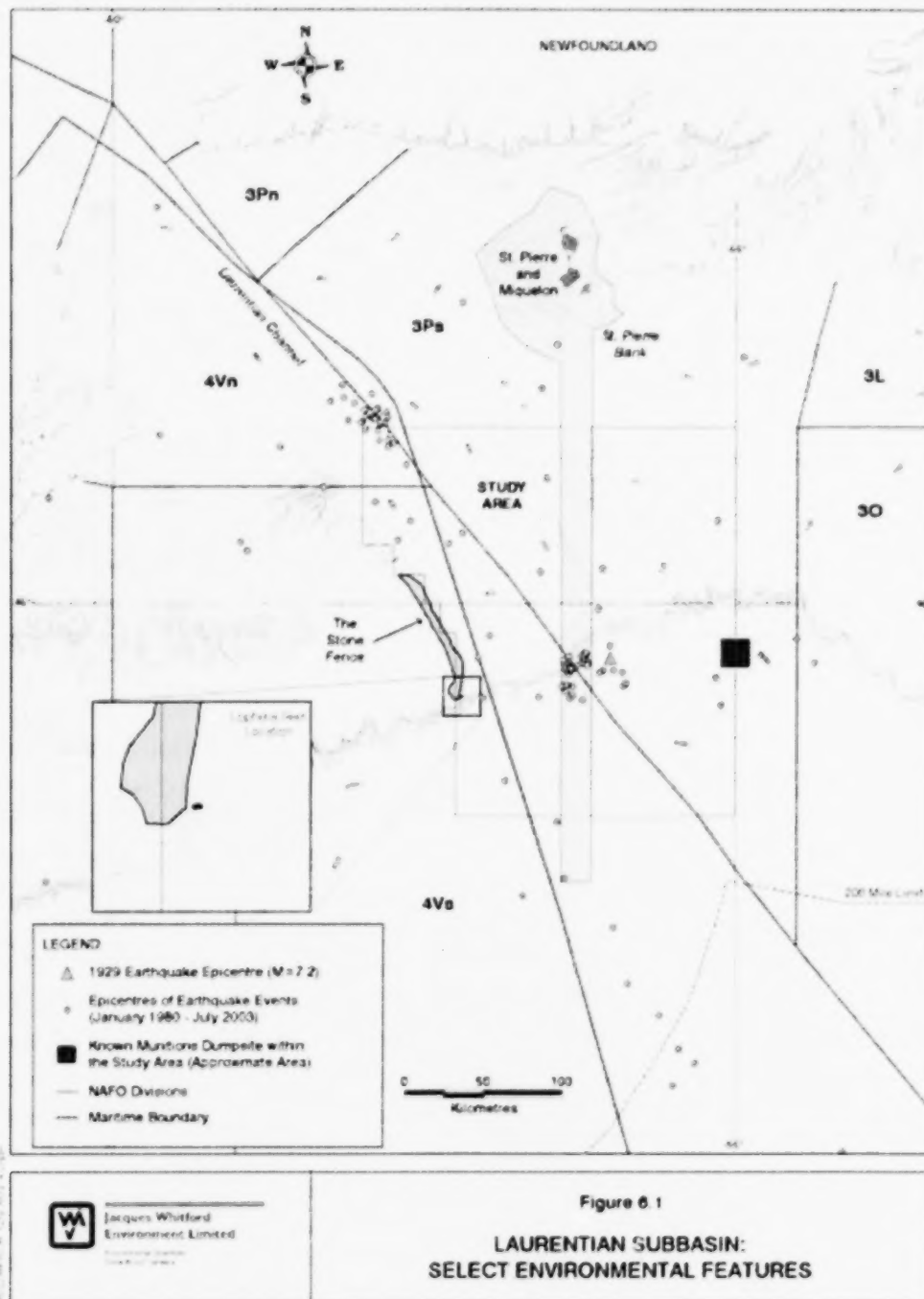
6.1 Environmental Planning and Management Considerations

Environmental considerations to help guide future planning and decision-making regarding offshore exploration in the Laurentian Subbasin are summarized below. A number of the key environmental features of the study area are illustrated in Figure 6.1.

6.1.1 Species at Risk

A number of species at risk are known or likely to occur in or adjacent to the Laurentian Subbasin, including several fish species (Atlantic cod, cusk, wolffish), marine birds (harlequin duck, piping plover, roseate tern, ivory gull), and marine mammals and sea turtles (15 species with designations in Canada and/or the United States), with a number of other species included on COSEWIC's Prioritized Candidate List (e.g., redfish). The Canadian *Species at Risk Act* has designated the following species that could be found in the Laurentian Subbasin under Schedule 1: piping plover *melodus* subspecies, roseate tern and leatherback turtle (Part 2 – Endangered Species); northern wolffish and spotted wolffish (Part 3 – Threatened Species); and the Eastern population of harlequin duck, ivory gull and Atlantic wolffish (Part 4 – Special Concern).

Figure 6.1 Laurentian Subbasin: Select Environmental Features



The promulgation of the federal *Species at Risk Act* in 2003 may have implications for planning and assessing offshore exploration in the region. Depending on the specific activity proposed and its location and timing, additional information may be useful to determine whether listed species and critical habitat are present and likely to be affected by proposed seismic surveys and drilling programs. In cases where species or habitats protected by the *Species at Risk Act* are known or expected to occur, the mitigation of any such effects will be an important consideration in decision-making related to offshore seismic surveys and exploration drilling programs.

6.1.2 Fish and Fish Habitat

As indicated in Section 3.2, a range of invertebrate and fish species inhabit the study area at different times of the year. A number of species are known or likely to spawn in different parts of the study area. The Laurentian Subbasin also serves as an important migration route for a number of fish species. In addition, some areas may be highly productive (e.g., the western edge of the St. Pierre Bank), and are therefore often critical locations for spawning and feeding fish.

The region is characterized by a complex spatial and temporal pattern of species presence, abundance, movement patterns, reproduction activity, and complex ecological relationships within and between species. This, and the somewhat broad level of information available regarding fish and fish habitat in the region, makes it difficult to specify particular sites which may be particularly sensitive during certain times. Planning for individual seismic programs should include consideration of the potential for fish spawning and migration activities in the general area. Scheduling should consider such periods and locations, and where possible be conducted so as to reduce potential interactions.

The Stone Fence is recognized as an area of special ecological and social importance, and should be given special consideration in planning and undertaking offshore drilling activity in the region. Extending for a distance of approximately 100 km along the southwestern side of the Laurentian Channel (Figure 3.8), this feature is known to provide habitat for a diverse benthic community and a variety of fish species, and is an important fishing area. Deep-sea corals are also known to occur in the area, which are of particular ecological importance and scientific and public interest, and are known to be particularly sensitive to the effects of offshore drilling activities. The existence of a *Lophelia* reef (approximately 1,000 m by 500 m) was confirmed in the Stone Fence area in September, 2003. A chemosynthetic benthic community was also discovered in the mid-1980s to the southeast of the Laurentian Subbasin.

Should exploration (particularly drilling) be proposed in the vicinity of the Stone Fence (or in other areas where coral aggregations or other sensitive features are known or likely to occur), additional measures to avoid or reduce potential effects may be considered. Expanding the scope of pre-drilling well site surveys to include the zone of influence of drill muds and cuttings (as determined by detailed dispersion modelling) would provide information on the benthic habitat within the area, including the

presence of any such features. Should corals or other sensitive features be found, additional mitigation measures may be required, such as restrictions on the at-sea discharge of waste material.

6.1.3 Marine Birds

A number of marine bird species use the Laurentian Subbasin area at various times of year. Species that winter in the area include the northern fulmar, dovekies, razorbills, puffins, glaucous gull, Iceland gull, and ivory gull. Common and thick-billed murres are most abundant during the winter, although they may be found year-round in the area. Similarly, herring gulls and great black-backed gulls are common and can be found in the study area throughout the year. Shearwater, Leach's storm-petrel, northern gannets, Arctic terns and common terns are predominantly found in the study area in summer.

A variety of coastal and nearshore birds may also be found in the region, including bald eagle, osprey, loons, grebes, great cormorant, double-crested cormorant, common eiders, scoters, long-tailed duck, mergansers, and harlequin duck. A variety of shorebird species occur in or near the study area, primarily as migrants foraging along the coastline. Piping plovers, listed as endangered by COSEWIC, and Schedule 1, Part 2 (Endangered) under the *Species at Risk Act*, also nest in small numbers along the south and west coast of Newfoundland, along the coast of Nova Scotia, and on Miquelon. Important bird areas in the region include Cape St. Mary's (nesting for northern gannets, black-legged kittiwakes, and common murres) and several islands near the Burin Peninsula, where large Leach's storm-petrel colonies are located.

Potential effects to marine birds as a result of routine activities relate primarily to lights, flares and vessel and aircraft movement. The anticipated level of exploration in the Laurentian Subbasin and the relatively short-term nature of these actions will likely mean that seismic surveys and drilling programs (and, possibly, any development projects) will likely be separated enough in space and time that a "reef effect" from drill rig and vessels lighting should not occur (i.e., marine birds would not perceive multiple structures as a continuous string of stimuli). However, the widespread and migratory nature of many marine bird species may increase the potential for cumulative environmental effects. The implementation of standard mitigation measures would reduce any potential effects to marine birds as a result of seismic surveys and drilling programs in the Laurentian Subbasin. The collection and release of stranded birds is one such measure to reduce the potential effects of the presence of offshore installations and their associated lights on marine birds during normal operational activities.

6.1.4 Marine Mammals and Sea Turtles

A number of marine mammal and sea turtle species are known or likely to occur in the Laurentian Subbasin. Reducing the potential for interactions with these species will be a key consideration in the design and conduct of seismic surveys and drilling programs in the region. Given the scientific and social importance of these species, the designation of many as species at risk, and the limits of the

existing information on their presence and distributions, especial care will be exercised in the review of seismic surveys or exploratory drilling programs proposed for the Laurentian Subbasin. In addition to standard mitigations, additional measures to avoid or reduce potential effects on marine mammals and sea turtles (e.g., surveillance prior to undertaking seismic surveys or using underwater explosives to remove wellheads) could also be considered.

6.1.5 Commercial Fisheries

A variety of commercial fisheries occur within the Laurentian Subbasin throughout the year. Potential interactions between offshore oil and gas operations and fishing activity are a primary issue of concern for both industries. Wherever possible, seismic surveys are to be planned to coordinate program activities with the fishing industry to reduce potential conflict with commercial fishing activity during peak fishing times. Consultation and communication between operators, regulators and the fishing industry concerning the design and implementation of individual surveys will be the most important means of reducing the potential for interactions between commercial fisheries and offshore exploration in the region.

6.1.6 Other Considerations

In addition, operators should consider the possibility of munitions being present in planning offshore work in the area (e.g., any "anomalies" noted during well-site surveys should be investigated prior to proceeding). The Department of National Defence has identified a 341.7 km² munitions dumpsite 276-m water depth in the Newfoundland and Labrador Offshore Area of the Laurentian Subbasin (Figure 6.1). As a result, the C-NOPB will require operators, as part of any future environmental assessment to be conducted in relation to proposed work or activity in this area, to address all possible environmental interactions and effects associated with the program. This information will be considered by the Board in the program review, which may result in the Board placing additional conditions on the program authorization or restricting certain activities in the area.

The study area lies within a region that is generally regarded as the most seismically active portion of the Newfoundland Continental Shelf, and a number of significant earthquakes have occurred in the general area in the past. Earthquake events have also been recorded within the study area in recent years, and although these have been of relatively low magnitude, they do illustrate the seismically active nature of the Laurentian Subbasin. The earthquake potential of the area will therefore require consideration in planning any future offshore petroleum activity in the Laurentian Subbasin.

6.1.7 Summary of Key Environmental Considerations

A number of key environmental planning and management considerations related to future offshore exploration in the Laurentian Subbasin are summarized below:

- Several species at risk are known or likely to occur in or adjacent to the Laurentian Subbasin. Mitigating potential effects to species and habitats protected by the new *Species at Risk Act* will be an important consideration in decisions related to future offshore exploration.
- A number of areas and times are particularly important to fish and fish habitat in the region (e.g., spawning areas and periods; migration routes; areas of high productivity). Individual seismic programs should where possible be planned so as to reduce potential interactions during particularly sensitive times.
- Should exploration (particularly drilling) be proposed in the vicinity of the Stone Fence (or in other areas with known or likely coral aggregations or other sensitive features), additional information collection and mitigation measures may help to reduce any potential effects.
- In addition to the implementation of standard mitigation measures, the collection and release of stranded birds on offshore installations may be required. As well, during sensitive periods such as nesting, seismic and exploration programs should, where possible, be planned to reduce potential interactions with bird colonies.
- A number of marine mammal and sea turtle species are known or likely to occur in the Laurentian Subbasin. In addition to standard mitigations, additional measures are available to help avoid or reduce potential effects on these species (e.g., surveillance), and may also be considered where necessary.
- Seismic surveys are, where possible, planned to coordinate program activities with the fishing industry to reduce potential conflict with commercial fishing activity during peak fishing times. On-going communication between the offshore petroleum and fishing industries is key. Currently, there is coordinated consultation with DFO research surveys to avoid timing conflicts.
- There is a known munitions dumpsite located on the southeastern edge of the study area (Figure 6.1), in the Newfoundland and Labrador Offshore Area of the Laurentian Subbasin. Operators should consider the possibility of underwater munitions being present in planning offshore work in the study area. The C-NOPB will require operators to consider potential interactions with such features in any future program-specific environmental assessments, which may result in the Board placing additional conditions on the program authorization or restricting certain activities in the area.
- The study area lies within a region which is generally regarded as the most seismically active portion of the Newfoundland Continental Shelf. The earthquake potential of the area will therefore require consideration in planning any future offshore petroleum activity in the Laurentian Subbasin.

6.2 Information Availability and Requirements

The availability of information varies considerably among the various components of the biophysical and socio-economic environments of the Laurentian Subbasin. Detailed information is, for example, available regarding commercial fishing activity in the region. However, there is less information currently available for other components, such as marine benthos, corals, sediment quality, marine mammals and sea turtles. Although the available information does allow for a general understanding of the environment of the study area, in some cases there may be a need for additional information to allow seismic surveys and drilling programs to be planned and implemented such that environmental effects are avoided or reduced. As discussed previously, for those environmental components for which there is limited existing information (e.g., marine mammals), especial care will be exercised in the review of seismic surveys or exploratory drilling programs proposed for the Laurentian Subbasin, with time, site and/or activity-specific mitigation measures implemented as required.

The information provided in this SEA, and that which may be gathered through program-specific environmental studies and assessments (e.g., dispersion modelling, site-specific benthic surveys) may help in designing and conducting specific seismic surveys and exploration drilling programs to reduce their environmental effects. Any future operational monitoring programs for marine birds and/or mammals which may be required as part of offshore exploration in the Laurentian Subbasin would also add to the overall knowledge base regarding the environment of the region.

A number of forthcoming information sources will also add considerably to this information base, and will be of use in planning and assessing future seismic surveys and drilling programs in the area. These include DFO databases on whale and dolphin sightings, underwater video surveys, and forthcoming ESRF-funded atlases of fish spawning locations and times on the Grand Banks and Scotian Shelf. Other government and industry-funded research programs may also consider future research programs aimed at collecting additional information on the environment of the region.

In terms of potential activities and their effects, many of the potential environmental issues associated with offshore oil and gas exploration are generally understood. Much of the existing knowledge is based on the results of scientific experiments and the experience of exploration drilling programs in other areas, as well as production-phase EEM programs for oil and gas development projects in Atlantic Canada. The ESRF is currently sponsoring a study of EEM programs for single-well exploration drilling programs (expected to be published later in 2003).

Information gaps related to the effects of seismic signals on invertebrates, fish, marine mammals and sea turtles have also been raised by some stakeholders. While information is available from other areas, it has been noted that additional work is required to more fully understand the magnitude and extent of the effects of seismic surveys on certain species in Atlantic Canadian waters (Thomson et al. 2000). An on-

going ESRF study on the effects of seismic surveys on shellfish in Atlantic Canada, for example, will provide additional, useful information on the effects of these activities in this region.

The propagation of seismic sound is largely determined by site-specific oceanographic characteristics. The attenuation characteristics of noise in the Laurentian Subbasin may be complex due to the range of bottom topographies present in the area. Depending on the level of activity proposed, the timing and location of proposed surveys and the presence of any known sensitive species or areas in the vicinity of a proposed survey, acoustical modelling and/or monitoring may also be useful in assessing the potential effects of individual seismic programs and in planning activities to reduce any potential interactions.

A review of the SEA will be undertaken in five years to determine if updates are necessary to reflect any new information which may become available over that period (e.g., that gathered through project-specific environmental assessments).

6.3 Cumulative Environmental Effects

The potential environmental effects of offshore seismic surveys and drilling programs in the Laurentian Subbasin may interact with each other and/or with other projects and activities in the region to result in cumulative environmental effects. As noted previously, the specific nature and spatial and temporal distribution of potential exploration is not currently known, although a number of assumptions have been made in assessing cumulative environmental effects. At this point, best estimates indicate that there may be a total of eight to ten exploration and delineation wells drilled in the area over the period of the licences, with a maximum of two wells drilled at any one time (one in shallow water and one in a deeper part of the area). It is anticipated that approximately two to three seismic surveys may be conducted annually over the next few years in the region. Seismic surveys tend to be undertaken sequentially in a given region, as operators often coordinate their programs to share a vessel when it is in an area.

The anticipated level of exploration in the Laurentian Subbasin and the relatively localized and short-term nature of these activities and many of their effects reduces the potential for cumulative effects. However, the often widespread nature of seismic surveys and other activities in the region (e.g., general vessel traffic, fishing activity), the potential for increased sound propagation in the deeper portions of the region, and the widespread and migratory nature of many species, makes such interactions possible.

Consideration of cumulative environmental effects will be an ongoing part of regulatory planning and decision-making regarding offshore exploration in the Laurentian Subbasin. This will minimize the potential for spatial and temporal interaction between individual seismic surveys and/or drilling programs in the area and their effects. The effects of seismic surveys and drilling programs may also act in combination with those of other unrelated projects and activities in the region (e.g., fishing activity, general marine traffic) to result in cumulative environmental effects. Cumulative effects will therefore

also be an important consideration in the environmental assessment and review of individual seismic surveys and exploration drilling programs, once specific locations and times are defined.

6.4 Conclusion

The SEA identified a munitions dumpsite location (44°38'N, 55°07'W; 44°38'N, 54°53'W; 44°48'N, 54°53'W; 44°48'N, 55°07'W) in the Newfoundland and Labrador portion of the study area; the contents of this dumpsite have not yet been established. No activity that involves direct physical disturbance of the seabed in the dumpsite area will be authorized until C-NOPB is satisfied that such activities in the area of the dumpsite will not pose a threat to human safety or the environment. Well site or geo-hazard surveys specifically designed for this area will be required prior to any authorization involving physical disturbance (e.g., seabed sampling, drilling programs).

A *Lophelia* coral reef approximately 500 m by 1,000 m in area has been identified in the Nova Scotia portion of the study area (centre point at 44°47'N, 57°20'W), in the vicinity of the "Stone Fence". Exploration drilling activities on this site or in the immediate vicinity that would necessitate the emplacement of moorings upon the site, may be restricted. In addition, any proposed exploratory drilling in the proximate area will require careful assessment to ensure that the treatment, handling and disposal of associated wastes are conducted in a manner that minimizes or eliminates potential environmental effects upon the site. Enhanced mitigation measures to reduce potential effects on the corals are likely to be required.

With the exception of the foregoing, the SEA indicates that exploration activities can be undertaken in the study area using the mitigative measures described in the document. A project-specific environmental assessment will be required for each proposed activity and this may identify additional mitigation measures in some cases. If it is determined during an assessment process that baseline information is required in order to assess effects predictions, the operator may then be required to undertake data collection. It is likely that during the early exploration phase, such data collection can be conducted opportunistically as part of ongoing industry activity. In the event that petroleum resources with development potential are discovered, the appropriate Board(s) will consult with the operator, government agencies and interested parties in the public to determine the more substantial data collection effort that would be required to support a future development application.

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APPENDIX A

Scientific Names for Species Described in the Report

COMMON NAME	SCIENTIFIC NAME
Fish and Fish Habitat	
Alewife	<i>Alosa pseudoharengus</i>
American eel	<i>Anguilla rostrata</i>
American plaice	<i>Hippoglossoides platessoides</i>
American straptail grenadier	<i>Ventrifossa occidentalis</i>
Arctic surf clam	<i>Spisula polynyna</i>
Atlantic argentine (aka. Smelt)	<i>Argentina silus</i>
Atlantic cod	<i>Gadus morhua</i>
Atlantic halibut	<i>Hippoglossus hippoglossus</i>
Atlantic herring	<i>Clupea harengus harengus</i>
Atlantic salmon	<i>Salmo salar</i>
Atlantic saury	<i>Scomberesox saurus</i>
Atlantic wolffish	<i>Anarhichas lupus</i>
Backfin tapirfish	<i>Lipogenys gilli</i>
Barndoor skate	<i>Raja laevis</i>
Bigeye tuna	<i>Thunnus obesus</i>
Black dogfish	<i>Centroscyllium fabricii</i>
Bluefish	<i>Pomatomus saltatrix</i>
Blue hake	<i>Antimora rostrata</i>
Blue shark	<i>Prionace glauca</i>
Brittlestar	<i>Ophiomusium lymani</i>
Capelin	<i>Mallotus villosus</i>
Cusk	<i>Brosme brosme</i>
Deep-sea cat shark	<i>Apristurus profundorum</i>
Deep-sea scallop	<i>Placopecten magellanicus</i>
Eelpout	<i>Lycodes sp.</i>
Greenland halibut	<i>Reinhardtius hippoglossoides</i>
Greenland shark	<i>Somniosus microcephalus</i>
Haddock	<i>Melanogrammus aeglefinus</i>
Hagfish	<i>Myxine glutinosa</i>
Hermit crab	<i>Pagurus sp.</i>
Iceland scallop	<i>Chlamys islandica</i>
Knifnose chimera	<i>Rhinochimaera atlantica</i>
Lanternfish	<i>Diaphus sp.</i>
Little skate	<i>Raja erinacea</i>
Lobster	<i>Homarus americanus</i>
Longfin hake	<i>Urophycis chesteri</i>
Longhorn sculpin	<i>Myoxocephalus octodecemspinosus</i>
Longnose eel	<i>Synophobranchus kaupii</i>
Lumpfish	<i>Cyclopterus lumpus</i>
Mackerel	<i>Scomber scombrus</i>
Mako shark	<i>Isurus oxyrinchus</i>
Marlin-spike (Common Grenadier)	<i>Nezumia bairdi</i>
Monkfish (Goosefish)	<i>Lophius americanus</i>
Northern sandlance	<i>Ammodytes dubius</i>
Northern shrimp	<i>Pandalus borealis</i>
Northern wolffish	<i>Anarhichas denticulatus</i>
Pollock	<i>Pollachius virens</i>
Porbeagle	<i>Lamna nasus</i>
Propeller clams	<i>Cyrtodaria siliqua</i>

COMMON NAME	SCIENTIFIC NAME
Red spider crab	<i>Hyas araneus</i>
Redfish	<i>Sebates</i> spp.
Rock crab	<i>Cancer irroratus</i>
Rock grenadier	<i>Coryphaenoides rupestris</i>
Sand dollar	<i>Echinarachnius parma</i>
Sea cucumber	<i>Pourtalesia wandeli</i>
Sea raven	<i>Hemitripterus americanus</i>
Sea urchin	<i>Strongylocentrotus droebachiensis</i>
Shortspine tapirfish	<i>Polyacanthonotus rissoanus</i>
Silver hake	<i>Merluccius bilinearis</i>
Smooth skate	<i>Raja senta</i>
Snow crab	<i>Chionoecetes opilio</i>
Shortspine tapirfish	<i>Polyacanthonotus rissoanus</i>
Shorttail (Jensen's) Skate	<i>Raja jenseni</i>
Slatjaw (Gray's) cutthroat eel	<i>Synaphobranchus kaupii</i>
Snubnose (slime) eel	<i>Simenchelys parasiticus</i>
Spiny dogfish	<i>Squalus acanthias</i>
Spiny eel	<i>Notacanthus chemnitzii</i>
Spinytail skate	<i>Raja spinicauda</i>
Spotted wolffish	<i>Anarhichas minor</i>
Squid	<i>Illex illecebrosus</i>
Stone crab	<i>Lithodes maia</i>
Swordfish	<i>Xiphias gladius</i>
Thorny skate	<i>Raja radiata</i>
Toad crab	<i>Hyas</i> spp.
Trunkfish	<i>Lactophrys trigonus</i>
Wedge clam	<i>Mesodesma deauratum</i>
White hake	<i>Urophycis tenuis</i>
Winter skate	<i>Leucoraja ocellata</i>
Witch flounder	<i>Glyptocephalus cynoglossus</i>
Yellowfin tuna	<i>Thunnus albacares</i>
Yellowtail flounder	<i>Limanda ferruginea</i>
Marine Birds	
American black duck	<i>Anas rubripes</i>
Arctic tern	<i>Sterna paradisaea</i>
Atlantic puffin	<i>Fratercula arctica</i>
Bald eagle	<i>Haliaeetus leucocephalus</i>
Black guillemot	<i>Cepphus grylle</i>
Black-legged kittiwake	<i>Rissa tridactyla</i>
Blue-winged teal	<i>Anas discors</i>
Canada goose	<i>Branta canadensis</i>
Caspian tern	<i>Sterna caspia</i>
Common eider	<i>Somateria mollissima</i>
Common goldeneye	<i>Bucephala clangula</i>
Common loon	<i>Gavia immer</i>
Common mergansers	<i>Mergus</i> spp.
Common murre	<i>Uria aalge</i>
Common tern	<i>Sterna hirunda</i>
Cory's shearwater	<i>Calonectris diomedea</i>
Double-crested cormorant	<i>Phalacrocorax auritus</i>

COMMON NAME	SCIENTIFIC NAME
Dovekie	<i>Alle alle</i>
Glaucous gull	<i>Larus hyperboreus</i>
Great black-backed gull	<i>Larus marinus</i>
Great cormorant	<i>Phalacrocorax carbo</i>
Greater scaup	<i>Aythya marila</i>
Greater shearwater	<i>Puffinus gravis.</i>
Green-winged teal	<i>Anas crecca</i>
Harlequin duck	<i>Histrionicus histrionicus</i>
Herring gull	<i>Larus argentatus</i>
Horned grebe	<i>Podiceps auritus</i>
Iceland gull	<i>Larus glaucoides</i>
Ivory gull	<i>Pogophila eburnea</i>
Jaegers	<i>Stercorarius sp.</i>
Leach's storm-petrel	<i>Oceanodroma leucorhoa</i>
Long-tailed duck	<i>Clangula hyemalis</i>
Mallard	<i>Anas platyrhynchos</i>
Manx shearwater	<i>Puffinus puffinus</i>
Northern fulmar	<i>Fulmaris glacialis</i>
Northern gannet	<i>Sula bassanus</i>
Northern pintail	<i>Anas acuta</i>
Osprey	<i>Pandion haliaetus</i>
Piping plover	<i>Charadrius melodus</i>
Razorbill	<i>Alca torda</i>
Red-necked grebe	<i>Podiceps grisegena</i>
Red-throated loon	<i>Gavia stellata</i>
Roseate tern	<i>Sterna dougallii</i>
Scoters	<i>Melanitta spp.</i>
Sooty shearwater	<i>Puffinus griseus</i>
Thick-billed murre	<i>Uria lomvia</i>
Wilson's storm-petrel	<i>Oceanites oceanicus</i>
Marine Mammals and Sea Turtles	
Atlantic white sided dolphin	<i>Lagenorhynchus acutus</i>
Bearded seal	<i>Erignathus barbatus</i>
Beluga whale	<i>Delphinapterus leucas</i>
Blue whale	<i>Balaenoptera musculus</i>
Blue whale	<i>Balaenoptera musculus</i>
Bottlenose dolphin	<i>Tursiops truncatus</i>
Common (saddleback) dolphin	<i>Delphinus delphis</i>
Fin whale	<i>Balaenoptera physalus</i>
Grey seal	<i>Halichoerus grypus</i>
Harbour porpoise	<i>Phocoena phocoena</i>
Harbour seal	<i>Phoca vitulina</i>
Harp seal	<i>Phoca groenlandica</i>
Hooded seal	<i>Cystophora cristata</i>
Humpback whale	<i>Megaptera novaeanglie</i>
Killer whale	<i>Orcinus orca</i>
Leatherback turtles	<i>Dermochelys coriacea</i>
Loggerhead turtles	<i>Caretta caretta</i>
Long finned pilot whale	<i>Globicephala melas</i>
Minke whale	<i>Balaenoptera acutorostrata</i>
Northern bottlenose	<i>Hyperoodon ampullatus</i>
Northern right whale	<i>Eubalaena glacialis</i>
Ringed seal	<i>Phoca hispida</i>
Sei whale	<i>Balaenoptera borealis</i>

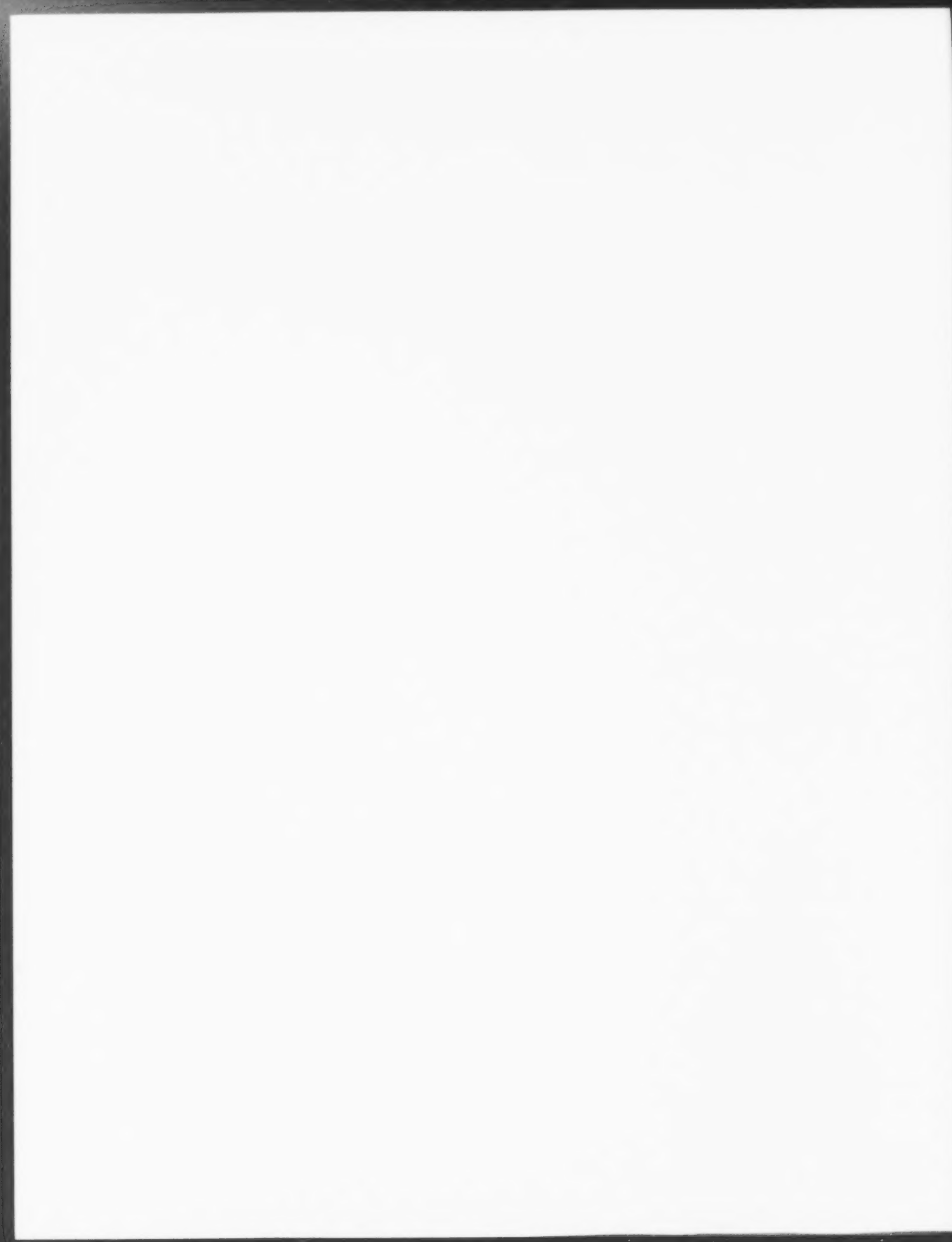
COMMON NAME	SCIENTIFIC NAME
Short-beaked common dolphin	<i>Delphinus delphis</i>
Sowerby's beaked whale	<i>Mesoplodon bidens</i>
Sperm whale	<i>Physeter macrocephalus</i>
Striped dolphin	<i>Stenella coeruleoalba</i>
Walrus	<i>Odobenus rosmarus</i>
White beaked dolphin	<i>Lagenorhynchus albirostris</i>
Fisheries	
Alewife	<i>Alosa pseudoharengus</i>
American eel	<i>Anguilla rostrata</i>
American plaice	<i>Hippoglossoides platessoides</i>
Arctic surf clam	<i>Spisula polynyna</i>
Atlantic cod	<i>Gadus morhua</i>
Atlantic halibut	<i>Hippoglossus hippoglossus</i>
Barndoor skate	<i>Raja laevis</i>
Bigeye tuna	<i>Thunnus obesus</i>
Bluefin tuna	<i>Thunnus thynnus</i>
Capelin	<i>Mallotus villosus</i>
Catfish (aka. Atlantic wolffish)	<i>Anarhichas lupus</i>
Cusk	<i>Brosme brosme</i>
Greenland halibut	<i>Reinhardtius hippoglossoides</i>
Haddock	<i>Melanogrammus aeglefinus</i>
Herring	<i>Clupea harengus harengus</i>
Iceland scallop	<i>Chlamys islandica</i>
Lobster	<i>Homarus americanus</i>
Lumpfish	<i>Cyclopterus lumpus</i>
Mackeral	<i>Scomber scombrus</i>
Mako shark	<i>Isurus oxyrinchus</i>
Monkfish	<i>Lophius americanus</i>
Northern shrimp	<i>Pandalus borealis</i>
Pollock	<i>Pollachius virens</i>
Porbeagle shark	<i>Lamna nasus</i>
Propeller clams	<i>Cyrtodaria siliqua</i>
Quahogs	<i>Mercenaria mercenaria</i>
Redfish	<i>Sebastes sp.</i>
Rock Crab	<i>Cancer irroratus</i>
Sea cucumber	<i>Pourtalesia wandeli</i>
Sea Scallop	<i>Placopecten magellanicus</i>
Sea urchin	<i>Strongylocentrotus droebachiensis</i>
Smooth skate	<i>Raja senta</i>
Snow crab	<i>Chionoecetes opilio</i>
Spider toad crab	<i>Hyas coarctatus</i>
Spinytail skate	<i>Raja spinicauda</i>
Squid	<i>Illex illecebrosus</i>
Swordfish	<i>Xiphias gladius</i>
Thorny skate	<i>Raja radiata</i>
White hake	<i>Urophycis tenuis</i>
Witch flounder	<i>Glyptocephalus cynoglossus</i>
Yellowfin tuna	<i>Thunnus albacares</i>
Yellowtail flounder	<i>Limanda ferruginea</i>

APPENDIX B

Additional Oceanographic Information

Ocean Currents

Primary Productivity



APPENDIX B

Currents

Current statistics for a number of locations within or immediately adjacent to the study area are provided in Table 1 (Bedford Institute of Oceanography 2003a). Figure 3.4 in the main report illustrates the current meter mooring locations.

Data are available for two sites directly within the Laurentian Subbasin area, located over the shelf in the southeast portion of the study area. Both are in the same general location, and together provide current data for each month of the year (1996-1997) at four depth intervals ranging from 50 m to 680 m. Current data are also available for two adjacent sites to the southwest of the study area, which together provide current data for the April – December period (1975), at four depths ranging from 200 m to 2,001 m. Some data are also available for a fifth site, located on the edge of Banqereau to the southwest of the study area (see Figure 3.4).

Table1: Current Statistics for Current Meter Moorings Within or Adjacent to the Study Area

Current Meter Mooring*	Moored Depth (m)	Date	Days	Maximum Speed (m/s)	Mean Speed (m/s)	Current Direction (T)
1 44 50.36 N 55 49.94 W	50	Nov 1996	24	0.653	0.225	264
		Dec 1996	31	0.822	0.280	262
		Jan 1997	31	0.554	0.160	256
		Feb 1997	28	0.668	0.292	261
		Mar 1997	31	0.592	0.173	250
		Apr 1997	30	0.511	0.073	284
		May 1997	2	0.307	0.105	312
	150	Nov 1996	24	0.348	0.092	264
		Dec 1996	31	0.502	0.144	263
		Jan 1997	31	0.467	0.077	247
		Feb 1997	28	0.511	0.146	263
		Mar 1997	31	0.421	0.062	253
		Apr 1997	30	0.397	0.062	66
		May 1997	2	0.148	0.038	335
	400	Nov 1996	24	0.229	0.007	30
		Dec 1996	31	0.441	0.058	276
		Jan 1997	31	0.296	0.008	301
		Feb 1997	28	0.302	0.051	280
		Mar 1997	31	0.331	0.033	275
		Apr 1997	30	0.339	0.020	322
		May 1997	2	0.203	0.136	281
	680	Nov 1996	24	0.220	0.010	356
		Dec 1996	31	0.232	0.007	10
		Jan 1997	31	0.212	0.009	317
		Feb 1997	28	0.244	0.015	334
		Mar 1997	31	0.270	0.008	349
		Apr 1997	30	0.191	0.015	315
		May 1997	2	0.156	0.041	286
2 44 50.39 N 55 49.95 W	50	Jun 1996	6	0.694	0.334	256
		Jul 1996	31	0.569	0.239	264
		Aug 1996	31	0.656	0.267	262
		Sept 1996	30	0.627	0.313	260
		Oct 1996	31	0.738	0.256	262
		Nov 1996	6	0.438	0.221	266
	150	Jun 1996	6	0.334	0.139	272
		Jul 1996	31	0.365	0.116	266
		Aug 1996	31	0.470	0.184	261

Current Meter Mooring*	Moor Depth (m)	Date	Days	Maximum Speed (m/s)	Mean Speed (m/s)	Current Direction (T)
		Sept 1996	30	0.531	0.161	262
		Oct 1996	31	0.444	0.175	262
		Nov 1996	6	0.397	0.192	263
	400	Jun 1996	6	0.212	0.041	263
		Jul 1996	31	0.194	0.009	273
		Aug 1996	31	0.275	0.062	270
		Sept 1996	30	0.403	0.039	263
		Oct 1996	31	0.345	0.043	268
		Nov 1996	6	0.249	0.080	285
	680	Jun 1996	6	0.142	0.003	31
		Jul 1996	31	0.156	0.006	1
		Aug 1996	31	0.136	0.009	2
		Sept 1996	30	0.272	0.010	341
		Oct 1996	31	0.217	0.009	29
Nov 1996		6	0.206	0.013	57	
3 44 01.50 N 56 55.90 W	200	Apr 1975	12	0.466	0.237	2
		May 1975	17	0.415	0.111	69
	500	Apr 1975	12	0.255	0.087	3
		May 1975	31	0.261	0.012	38
		Jun 1975	30	0.187	0.040	270
		Jul 1975	31	0.120	0.004	170
		Aug 1975	13	0.202	0.065	68
	1,000	Apr 1975	12	0.148	0.032	57
		May 1975	31	0.128	0.011	14
		Jun 1975	30	0.111	0.015	352
		Jul 1975	31	0.022	0.004	160
	2,001	Aug 1975	12	0.147	0.031	245
		Apr 1975	12	0.075	0.020	82
		May 1975	31	0.117	0.012	25
		Jun 1975	30	0.128	0.021	308
		Jul 1975	31	0.171	0.023	303
	4 44 01.90 N 56 57.80 W	200	Aug 1975	12	0.025	0.012
Aug 1975			19	0.392	0.216	57
Sept 1975			30	0.306	0.028	63
Oct 1975			31	0.327	0.102	237
Nov 1975			30	0.294	0.071	260
500		Dec 1975	3	0.222	0.089	201
		Aug 1975	19	0.177	0.067	46
		Sept 1975	30	0.158	0.012	42
		Oct 1975	31	0.144	0.049	249
		Nov 1975	30	0.220	0.073	254
1,000		Dec 1975	3	0.191	0.081	238
		Aug 1975	19	0.095	0.026	91
		Sept 1975	30	0.075	0.003	97
		Oct 1975	31	0.139	0.038	300
		Nov 1975	30	0.165	0.060	300
2,001		Dec 1975	3	0.152	0.090	302
		Aug 1975	19	0.080	0.014	158
		Sept 1975	30	0.076	0.011	358
		Oct 1975	31	0.099	0.007	290
		Nov 1975	30	0.165	0.039	305
5 44 35.09 N 57 41.58 W	49	Dec 1975	3	0.123	0.071	293
		Jun 1975	19	0.476	0.065	229
	63	Jul 1975	15	0.636	0.102	228
		Jun 1975	15	0.305	0.037	243
	* See Figure 3.4 for locations of current meter moorings					
Source: Bedford Institute of Oceanography (2003a)						

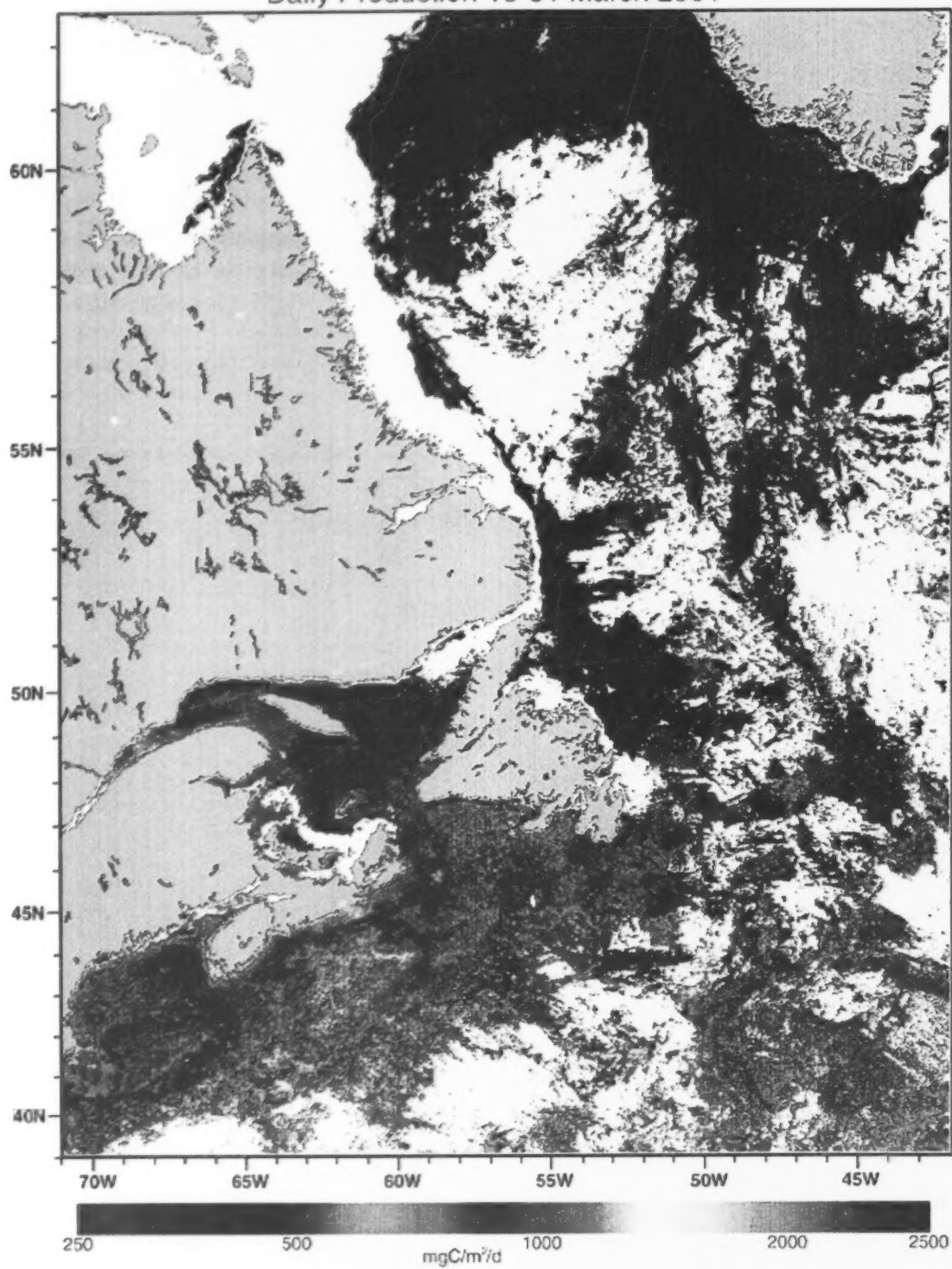
Primary Productivity

The following maps provide an indication of primary productivity in the waters off Newfoundland and Labrador and Nova Scotia. Maps are provided for select months in 2001, in order to illustrate general spatial and temporal trends in primary production in the region.

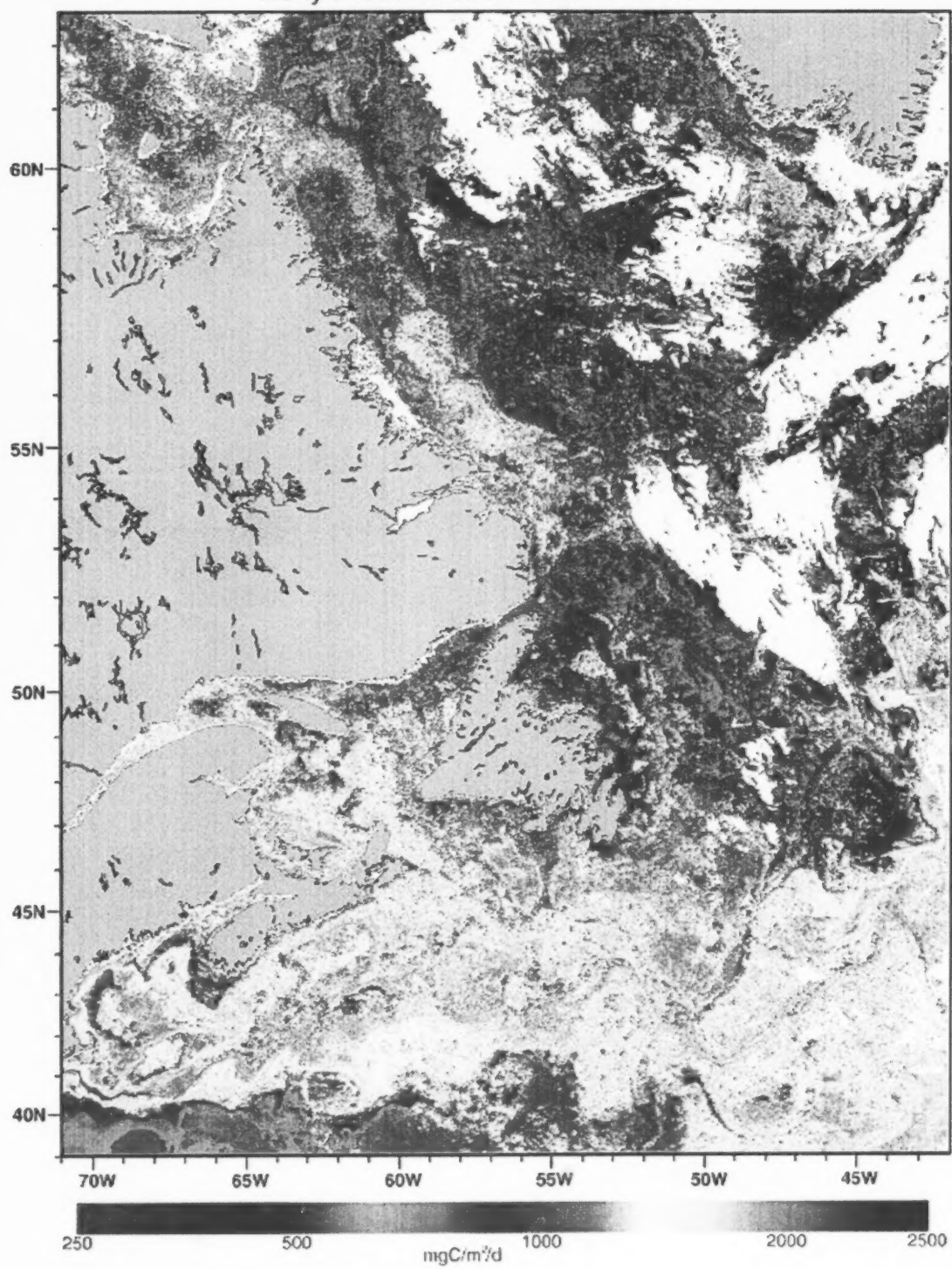
Source: Biological Oceanography, Bedford Institute of Oceanography (Reproduced with permission)

Bedford Institute of Oceanography. 2003. Remote Sensing of Ocean Colour, Temperature and Primary Productivity (Semi-Monthly Composite Images). http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/seawifs/seawifs_3.html (Accessed February 6, 2003).

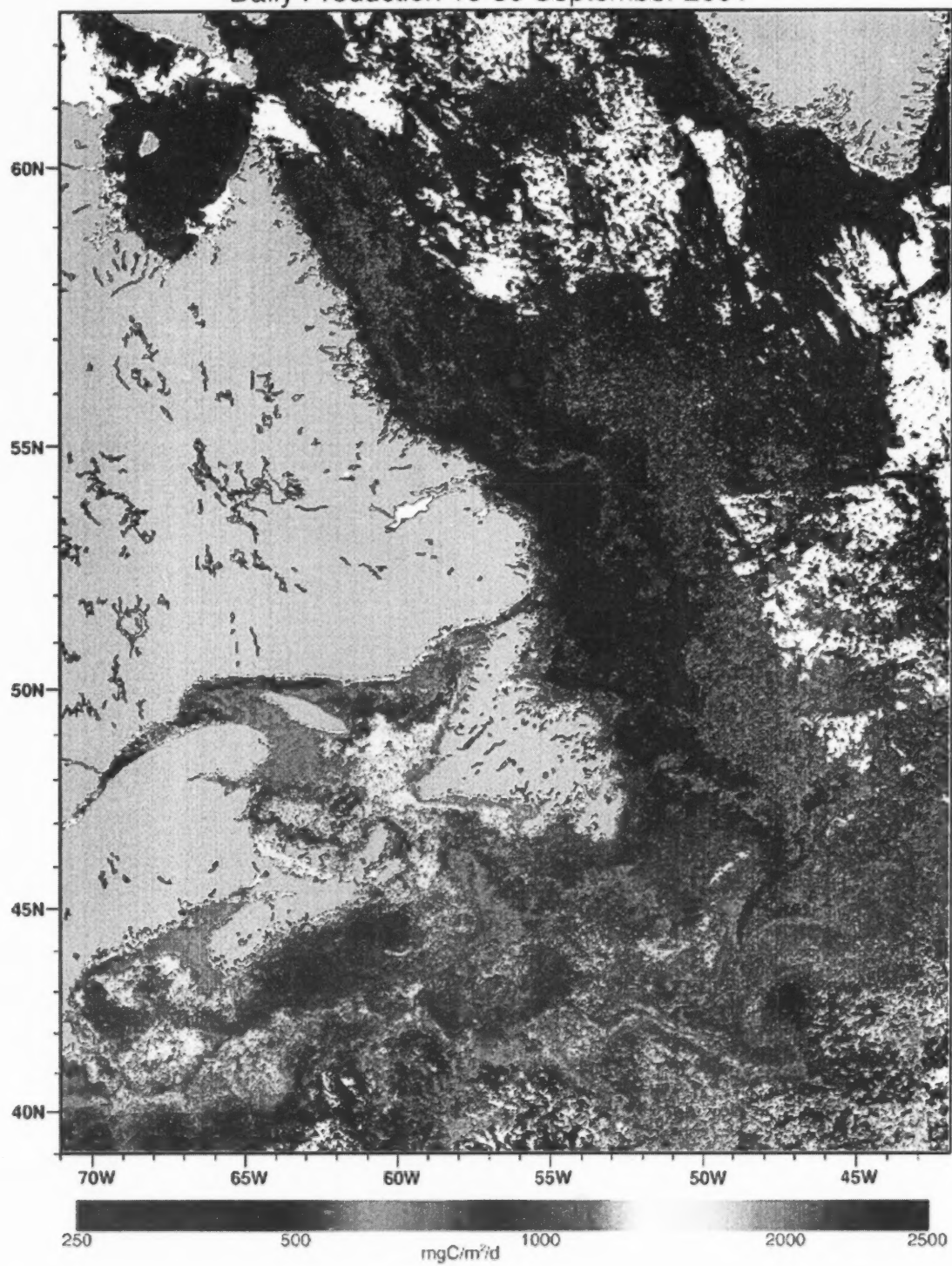
Daily Production 15-31 March 2001



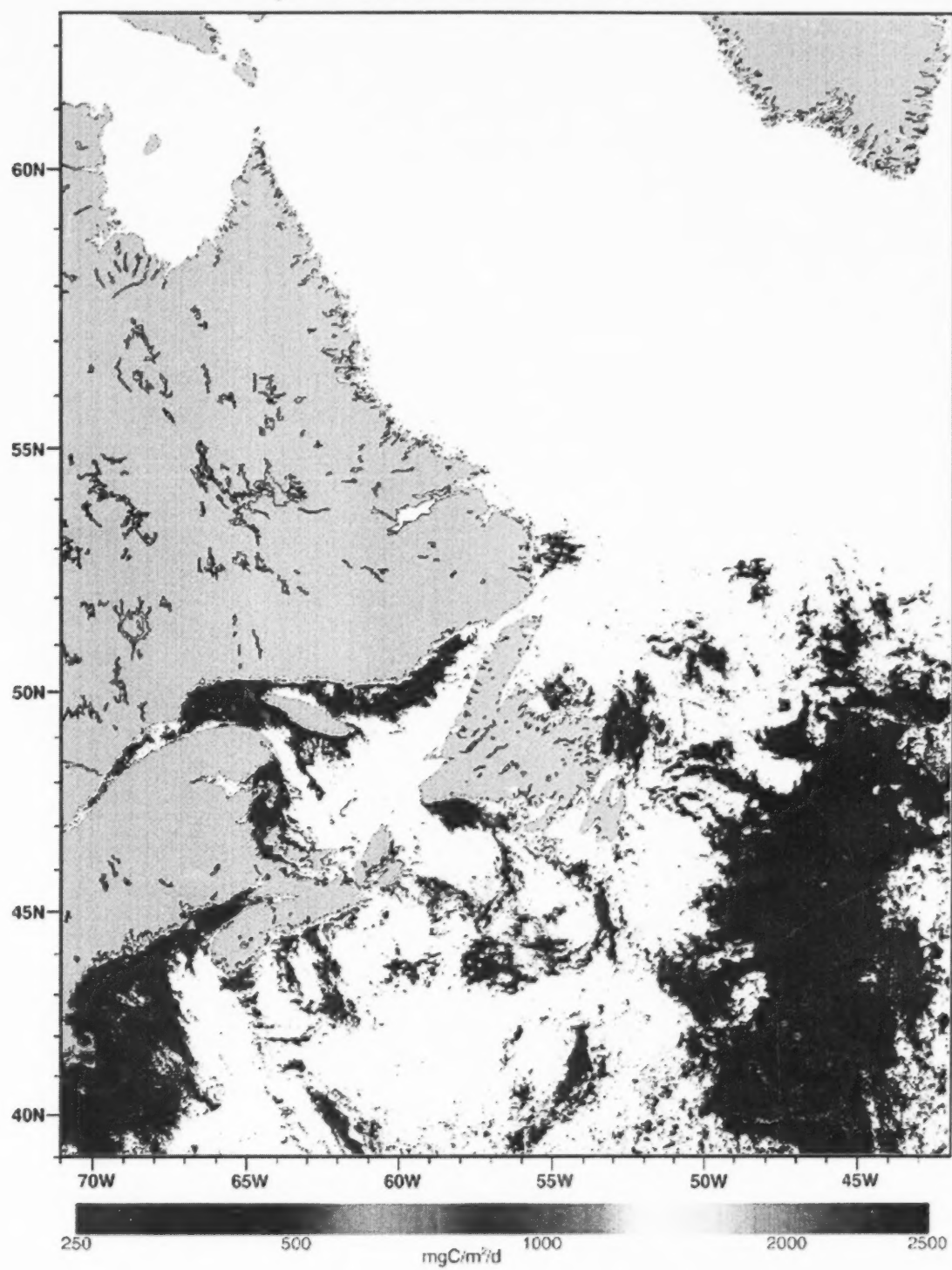
Daily Production 16-30 June 2001



Daily Production 16-30 September 2001



Daily Production 16-31 December 2001



APPENDIX C

Fisheries Statistics and Distribution Maps

Table 1. Summary of Valid Geospatial Coordinates per NAFO Unit Area (1995 - 2001)

NAFO Unit Area	# Valid	# Missing	Total	% Valid	% Missing
3La	2714	37327	40041	7	93
3Lb	4402	27114	31516	14	86
3Lc	8542	379	8921	96	4
3Lf	2817	14194	17011	17	83
3Lg	4541	1085	5626	81	19
3Lj	1626	4532	6158	26	74
3Lq	2236	3402	5638	40	60
3Ls	759	18	777	98	2
3Oa	4234	50	4284	99	1
3Ob	3026	9	3035	100	0
3Oc	11669	61	11730	99	1
3Od	3139	24	3163	99	1
3Oe	8344	135	8479	98	2
3Psa	2790	19680	22470	12	88
3Psb	11166	50068	61234	18	82
3Psc	23795	45708	69503	34	66
3Psd	4904	198	5102	96	4
3Pse	2936	456	3392	87	13
3Psf	11190	1254	12444	90	10
3Psg	3881	376	4257	91	9
3Psh	9139	710	9849	93	7
3Ps	0	5	5	0	100
3Pu	55	95	150	37	63
4V	10	0	10	100	0
4Vsb	3191	3	3194	100	0
4Vsc	19952	177	20129	99	1
4Vse	306	1	307	100	0
4Vn	15730	41468	57198	28	72
4Wd	11914	12191	24105	49	51
4We	2581	3	2584	100	0
4Wf	1353	4	1357	100	0
4Wg	2929	1	2930	100	0
4Wh	3404	6	3410	100	0
4Wj	4171	18	4189	100	0
4Wk	8463	15613	24076	35	65
4Wl	6937	59	6996	99	1
4Wm	1665	7	1672	100	0

Table 2 Summary of Valid Geospatial Coordinates per Species (1995 - 2001)

Species	# Valid	# Missing	Total%	Valid	% Missing
Bigeye Tuna	832	2	834	100	0
Yellowtail Flounder	13362	75	13437	99	1
Redfish	22980	395	23375	98	2
Monkfish	1515	27	1542	98	2
Skate	6369	122	6491	98	2
Shrimp	29944	647	30591	98	2
Yellowfin Tuna	548	13	561	98	2
Greenland Halibut	9970	277	10247	97	3
Arctic Surf Clams	6431	227	6658	97	3
Swordfish	9238	354	9592	96	4
Mackerel and Mako Shark	339	13	352	96	4
Porbeagle Shark	2475	182	2657	93	7
Sea Scallops	5332	394	5726	93	7
American Plaice	3462	262	3724	93	7
Cusk	521	42	563	93	7
Atlantic Halibut	10355	1133	11488	90	10
Witch Flounder	2446	284	2730	90	10
Cod	27872	5089	32961	85	15
Snow Crab	95998	18721	114719	84	16
Bluefin Tuna	1833	383	2216	83	17
Spider-Toad Crab	223	50	273	82	18
White Hake	3098	757	3855	80	20
Haddock	338	115	453	75	25
Pollock	1941	691	2632	74	26
Catfish	46	35	81	57	43
Herring	3276	2610	5886	56	44
Iceland Scallop	8340	7098	15438	54	46
Rock Crab	1858	1847	3705	50	50
Lumpfish	818	1869	2687	30	70
Capelin	1097	2628	3725	29	71
Sea Urchins	544	2875	3419	16	84
Squid	130	828	958	14	86
Mackerel	568	6883	7451	8	92
Alewife	1	102	103	1	99
Lobster	21	51548	51569	0	100

Table 3 Annual Catch per NAFO Area (1995-2001)

Year	Value (\$)	Live Weight (kg)
NAFO Division 3Ps		
1995	30,607,880	13,946,693
1996	24,436,032	14,867,036
1997	42,712,613	32,278,116
1998	57,765,529	42,977,905
1999	83,615,419	48,161,776
2000	87,576,046	46,215,372
2001	66,628,192	35,911,712
NAFO Division 4Va		
1995	32,376,987	14,118,762
1996	22,670,094	11,076,942
1997	22,492,940	11,159,764
1998	19,748,073	9,032,093
1999	25,034,112	9,332,642
2000	27,795,986	7,451,704
2001	-	7,319,775
NAFO Division 4Vs		
1995	27,034,426	22,339,262
1996	31,199,002	26,932,156
1997	27,547,531	27,861,086
1998	30,857,286	31,127,045
1999	35,379,624	35,383,544
2000	44,482,174	30,038,444
2001	-	23,727,900
NAFO Unit Area 3Psf		
1995	5,947,629	1,427,664
1996	3,994,702	1,599,696
1997	6,749,030	3,689,904
1998	7,443,414	4,417,523
1999	16,723,961	6,990,694
2000	21,268,085	6,464,251
2001	16,446,971	5,590,848
NAFO Unit Area 3Psg		
1995	781,386	951,212
1996	368,088	367,236
1997	3,274,832	3,031,282
1998	2,678,858	4,061,951
1999	3,004,800	4,673,313
2000	2,180,861	4,596,848
2001	616,524	940,114
NAFO Unit Area 3Psh		
1995	1,971,257	1,736,479
1996	1,268,300	1,297,929
1997	1,550,834	1,861,406
1998	5,488,128	5,794,797
1999	4,954,879	4,657,283
2000	7,542,241	6,817,241
2001	5,355,202	5,601,436
NAFO Unit Area 4Vsb		
1995	2,084,937	419,306
1996	2,055,537	472,329
1997	1,862,806	504,005
1998	1,473,337	648,339
1999	2,979,290	1,091,824
2000	11,170,076	2,463,248
2001	-	2,067,509
NAFO Unit Area 4Vsc		
1995	23,291,585	21,397,698
1996	28,564,038	26,144,171
1997	24,926,210	26,927,773
1998	28,900,414	30,319,509
1999	31,910,782	34,017,475
2000	33,123,716	27,532,051
2001	-	21,398,106

Table 4a Catch by Species in NAFO Division 3Ps

Species	1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	545968	594000	6936754	24678939	38997916	31387989	18213520	121355085
	Weight(kg)	533841	641099	7594686	16717276	24737917	20382158	13715472	84322449
HADDOCK	Value(\$)	83238	144316	66633	219827	87401	155165	125261	881841
	Weight(kg)	68902	139933	75029	242791	105451	173419	139917	945442
REDFISH	Value(\$)	900443	1921363	1980621	3116405	2622003	3225586	2071611	15838032
	Weight(kg)	2743554	5878926	5295823	8129196	6627836	8454039	4127047	41256421
ATLANTIC HALIBUT	Value(\$)	706865	333956	555563	1015283	891258	1002093	700008	5205026
	Weight(kg)	100818	60040	99252	163127	131977	140716	267770	963900
AMERICAN PLAICE	Value(\$)	99268	95751	167005	291324	450018	430835	769480	2303682
	Weight(kg)	84199	114226	220312	496337	618553	607772	907948	2959347
YELLOWTAIL FLOUNDER	Value(\$)	3199	5722	3831	27586	42619	91071	133153	307200
	Weight(kg)	4373	7022	4529	55674	68833	144681	154090	439202
WITCH FLOUNDER	Value(\$)	327657	227318	194698	262833	341599	237765	459327	2051197
	Weight(kg)	274174	256511	289243	457605	527331	338085	476367	2619316
WINTER FLOUNDER	Value(\$)	172123	166765	139142	128689	138160	169447	112922	1027249
	Weight(kg)	244038	237972	235031	206636	226562	278095	185340	1613674
GREENLAND HALIBUT	Value(\$)	187237	264571	350871	473084	351143	509529	171371	2307807
	Weight(kg)	86978	154924	342997	254355	247567	365992	209936	1662749
FLOUNDERS	Value(\$)	2741	360	4048	903	20	5446	876	14393
	Weight(kg)	5195	507	2296	604	24	6554	3120	18300
SKATE	Value(\$)	592360	244637	294153	347978	345598	274261	481160	2580147
	Weight(kg)	1863914	603064	828776	1258320	1101758	934627	1767905	8358364
POLLOCK	Value(\$)	292243	221092	312947	350335	411804	489595	373259	2451275
	Weight(kg)	312862	375173	594109	642390	751429	826331	822151	4325445
WHITE HAKE	Value(\$)	394617	264038	213107	365034	349248	515106	494225	2595375
	Weight(kg)	426611	357458	315093	565736	573384	975421	917584	4131297
CUSK	Value(\$)	1049	160	848	4853	5663	3727	1267	17597
	Weight(kg)	1670	351	981	5501	7578	4345	6478	26911
CATFISH	Value(\$)	49788	28297	65934	26689	63114	75960	47706	357488
	Weight(kg)	13577	840	46608	93680	228937	276811	119284	787297
LUMPFISH ROE	Value(\$)	4705970	3668720	5317846	1694781	2957194	1650607	1235984	21231102
	Weight(kg)	714016	562292	1150818	769113	1161886	710960	260698	5329783
MONKFISH	Value(\$)	269123	161106	114644	232600	105553	51212	335837	1270074
	Weight(kg)	188799	110666	111681	165025	67197	35440	275356	954164
HERRING	Value(\$)	176892	71795	320122	248090	118518	207291	279637	1422344
	Weight(kg)	1099178	368310	2456349	1608806	785945	1368139	1652838	9339565
MACKEREL	Value(\$)	11733	3436	8884	79	214	33203	57550	8221
	Weight(kg)	38951	11683	26696	193	972	170800	249295	35614
SWORDFISH	Value(\$)	26234	20527	11767	3998	27566	7490	97584	13941
	Weight(kg)	3236	2802	3250	505	5284	1104	16181	2312
BIGEYE TUNA	Value(\$)	39					6651		6689
	Weight(kg)	8		431			954		1393
BLUEFIN TUNA	Value(\$)		42488		42237	23954	107386	209448	425514
	Weight(kg)		3630		4059	2302	10321	13037	33349
YELLOWFIN TUNA	Value(\$)	10	249						258
	Weight(kg)	3	40	113					156
ALEWIFE	Value(\$)		54						54
	Weight(kg)		162						162
EELS	Value(\$)	30230	50616	40066	23376	17063	8445	3039	168836
	Weight(kg)	6102	8297	7325	4713	1985	1719	790	30931
CAPELIN	Value(\$)	2408	5977	243386	117995	7151			376917
	Weight(kg)	8404	61840	1152305	582312	77452			1882313
PORBEAGLE SHARK	Value(\$)	457759	290641	151201	173046	189524	293040	19286	1574498
	Weight(kg)	199744	137331	68535	87068	127457	133394	11374	764903
MACKEREL AND MAKO SHARK	Value(\$)	2242	2137	3861	4351	5498	5217	4222	27527
	Weight(kg)	1441	1316	4704	4125	3982	3770	3269	22607
SEA SCALLOPS	Value(\$)	983009	207215	49938	434854	110223	177510	490347	2453096
	Weight(kg)	729827	160570	34426	272459	72705	124355	330302	1724644
SQUID	Value(\$)	8289	27866	24618	609			18	61401
	Weight(kg)	23100	68757	82165	1119			55	175196
ICELAND SCALLOPS	Value(\$)	1529264	859908	9370516	4529393	1931766	1826117	718074	20765038
	Weight(kg)	1275078	688980	5862026	2835265	1213144	1147063	491187	13512743
SEA URCHINS	Value(\$)	34465	19917	3002	1597	365	47006	122927	229277
	Weight(kg)	33508	14076	2353	1510	331	27849	67823	147450
LOBSTER	Value(\$)	7206451	6611229	6218806	6179832	5761533	6835201	8608133	47421185
	Weight(kg)	766571	691514	616936	664184	611460	635812	704775	4691252
SPIDER-TOAD CRAB	Value(\$)	11		296			15586	15152	31044
	Weight(kg)	10		448			18845	18032	37335
SHRIMP	Value(\$)	91	2058	847	61674	175621	215126	64478	519895
	Weight(kg)	35	1333	5291	55460	126458	154870	53173	396620
ROCK CRAB	Value(\$)	205		72				14031	14308
	Weight(kg)	295		109				20522	20926
SNOW CRAB	Value(\$)	10649883	7759881	9519637	12675272	27041609	17507729	30223936	135377946
	Weight(kg)	1934247	3062863	4744497	6627973	7913491	7913086	7867150	40063307
OTHER	Value(\$)	154894	117900	35583	23176	48618	40361	95294	515826
	Weight(kg)	159850	73977	28936	68086	35367	16754	150120	533090
Total	Value(\$)	30607880	24436032	42712613	57765529	83615419	87576046	66628192	393341711
	Weight(kg)	13946693	14867036	32278116	42977905	48161776	46215372	35911712	234358610

Table 4b Catch by species in NAFO Division 4Vn

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	53060	70612	158062	320510	509539	411387	-	1523169	253862
	Weight(kg)	49848	68074	118234	299436	348569	270418	209066	1363645	194806
HADDOCK	Value(\$)	1244	1246	2222	3335	2324	3668	-	14039	2340
	Weight(kg)	1406	919	1537	2386	1364	1768	1548	10928	1561
REDFISH	Value(\$)	1600555	609755	816381	1238156	1020939	611901	-	5897687	982948
	Weight(kg)	3537285	1202294	1759831	1462976	1790504	1384275	793916	11931081	1704440
ATLANTIC HALIBUT	Value(\$)	93469	132106	160667	192398	243439	188744	-	1010823	168471
	Weight(kg)	14884	19048	24373	31353	37643	22718	29586	179605	25658
AMERICAN PLAICE	Value(\$)	228141	365863	830554	620089	620988	261110	-	2926746	487791
	Weight(kg)	155313	243639	524030	515137	634308	240155	138938	2451520	350217
YELLOWTAIL FLOUNDER	Value(\$)	1158							1158	193
	Weight(kg)	1092							1092	156
WITCH FLOUNDER	Value(\$)	653739	484275	472877	571020	298526	345308	-	2825744	470957
	Weight(kg)	255242	331279	292746	415280	224087	237154	245890	2001678	285954
WINTER FLOUNDER	Value(\$)	138	4986		3573		1		8699	1450
	Weight(kg)	61	2927		1908		1		4797	685
GREENLAND HALIBUT	Value(\$)	8379	18883	16617	17825	32640	14912	-	109256	18209
	Weight(kg)	9982	12985	14582	24260	31551	15479	13170	122009	17430
FLOUNDERS	Value(\$)	578826	292103	317872	220011	53835	21614		1484260	247377
	Weight(kg)	281152	189445	173632	143801	61047	16342		865419	123631
SKATE	Value(\$)	249	5849	48		1		-	6147	1024
	Weight(kg)	1028	20004	123				6300	27455	3922
POLLOCK	Value(\$)	196453	21388	4173	106124	21213	5200		354551	59092
	Weight(kg)	396946	30013	10467	155070	29380	5930	51	627857	89694
WHITE HAKE	Value(\$)	24518	52360	125447	112112	103062	89682	-	507180	84530
	Weight(kg)	32382	68422	140677	137937	137181	95862	54385	666846	95264
CUSK	Value(\$)	1169	38	370	218	450	710	-	2956	493
	Weight(kg)	1216	46	402	242	504	753	7	3170	453
CATFISH	Value(\$)	643	471	1218	1509	1719	1288	-	6847	1141
	Weight(kg)	1926	1692	4225	4955	3892	3184	2475	22349	3193
LUMPFISH	Value(\$)	35969	21158	3096					60223	10037
	Weight(kg)	21752	0	0					21752	3107
MONKFISH	Value(\$)	9729	942	1588	371	220	765	-	13615	2269
	Weight(kg)	12011	1696	1647	523	335	837	1344	18393	2628
HERRING	Value(\$)	719152	685305	599645	289472	308457	251148	-	2853379	475563
	Weight(kg)	4558870	4782118	4325095	2204961	1761729	942358	1523402	20098533	2871219
MACKEREL	Value(\$)	733694	827380	452877	254430	315245	258461	-	2842087	473681
	Weight(kg)	1492264	1593739	835458	553611	757349	725379	123570	6081370	868767
SWORDFISH	Value(\$)	7428	14280	7146	1418	2720		-	32992	5499
	Weight(kg)	948	1633	937	223	362		5314	9417	1345
BIG EYE TUNA	Value(\$)				1045				1045	
	Weight(kg)				158				158	26
YELLOWFIN TUNA	Value(\$)				752				752	125
	Weight(kg)				131				131	22
ALEWIFE	Value(\$)	42847	50953	50804	55199	42021	26462	-	268287	44714
	Weight(kg)	124128	162409	227968	167008	157377	99450	50335	988675	141239
EELS	Value(\$)	88981	138768	73410	38829	50124	27647		417760	69627
	Weight(kg)	20827	29379	12937	14884	16474	8358		102859	14694
CAPELIN	Value(\$)				5000				5000	833
	Weight(kg)				22680				22680	3240
PORBEAGLE SHARK	Value(\$)	125946	43159	71747	21684	12680	37545	-	312761	52127
	Weight(kg)	57132	19686	32581	9910	8537	17033	98	144977	20711
MACKEREL AND MAKO SHARK	Value(\$)	2369	40	758	344	298	111	-	3920	653
	Weight(kg)	1692	20	422	195	165	76	46	2616	374
ARCTIC SURF CLAMS	Value(\$)			2526					2526	421
	Weight(kg)			2874					2874	411
SEA SCALLOPS	Value(\$)	9538	32673	24496	18660	30468			115834	19306
	Weight(kg)	5359	16406	11530	7997	13472			54764	7823
SQUID	Value(\$)			432		909	3	-	1344	224
	Weight(kg)			653		1373	4	908	2938	420
SEA URCHINS	Value(\$)	58368	70686	158041	110987	217663	238445	-	854189	142365
	Weight(kg)	26680	39452	76486	53939	85447	87108	26981	396093	56585
LOBSTER	Value(\$)	21642654	14692849	13941047	12117893	16126185	16786139	-	95306767	15884461
	Weight(kg)	2030407	1518809	1292817	1266217	1329088	1417210	1741376	10595924	1513703
SPIDER-TOAD CRABS	Value(\$)	56413		77	282	164		-	56936	9489
	Weight(kg)	85295		209	640	186		8983	95313	13616
SHRIMP	Value(\$)	246800	42603	757949	798002	1025373	597682	-	3468409	578068
	Weight(kg)	160140	24379	467349	443025	591471	275948	510323	2472635	353234
CRAB, ROCK	Value(\$)	73460	56477	81156	146694	168739	287494	-	814020	135670
	Weight(kg)	115323	100533	122593	219133	202548	217090	250627	1227847	175407
SNOW CRAB	Value(\$)	5045135	3921575	3299715	2402882	3804119	7314345	-	25787770	4297962
	Weight(kg)	651471	593084	637342	807451	1098839	1360363	1516032	6664582	952083
OTHER	Value(\$)	36565	11315	59922	19319	20052	14214	-	161387	26998
	Weight(kg)	14700	2912	46007	14909	7860	6451	65104	157943	22563
Total	Value(\$)	32376987	22670094	22492940	19690143	25034112	27795986	-	150060262	25010044
	Weight(kg)	14118762	11076942	11159764	8982336	9332642	7451704	7319775	69441925	9920275

Table 4c Catch by species for NAFO Division 4Vs

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	165875	143151	125200	146949	274159	117798	-	973132	162189
	Weight(kg)	184669	158230	110138	109610	209346	90578	75993	938564	134081
HADDOCK	Value(\$)	78866	57527	36784	26931	38969	26497	-	265574	44262
	Weight(kg)	57701	44687	24250	16232	27922	19400	23340	213532	30505
REDFISH	Value(\$)	1325593	466798	548286	150098	745819	460257	-	3696851	616142
	Weight(kg)	4254742	1599811	2031831	532448	2420856	1394095	3939076	16172859	2310408
ATLANTIC HALIBUT	Value(\$)	1092403	815321	1286350	818878	899363	765181	-	5697495	949583
	Weight(kg)	144540	130275	171623	114987	115751	94926	168126	940228	134318
AMERICAN PLAICE	Value(\$)	271648	547104	668139	603261	529265	339628	-	2959046	493174
	Weight(kg)	202180	374961	404672	560339	534966	308164	143405	2528687	361241
YELLOWTAIL FLOUNDER	Value(\$)	955655	496040	66979	37339	42584	7319	-	1605916	267653
	Weight(kg)	730488	388888	75983	31797	42937	5531	7667	1283291	183327
WITCH FLOUNDER	Value(\$)	123371	55745	83565	44221	19204	11973	-	338078	56346
	Weight(kg)	53899	35337	57321	33620	17098	7999	5866	211140	30163
WINTER FLOUNDER	Value(\$)	14	10	3237	-	-	11559	-	14820	2470
	Weight(kg)	28	9	1958	-	-	7490	-	9485	1355
GREENLAND HALIBUT	Value(\$)	3533	3195	3311	3653	6298	17731	-	37720	6287
	Weight(kg)	4436	3986	3963	3087	10619	16538	13151	55780	7969
FLOUNDERS	Value(\$)	961193	536537	843199	214928	296635	294364	-	3146856	524476
	Weight(kg)	628072	337984	495641	201348	336112	222589	168930	2390676	341525
SKATE	Value(\$)	814837	477493	300348	142087	166593	117186	-	2018544	336424
	Weight(kg)	1506913	1372120	911010	394335	465981	366368	245952	5262679	751811
POLLOCK	Value(\$)	304007	206563	110760	123462	262782	181535	-	1189109	198185
	Weight(kg)	665367	437369	134753	170926	426027	234827	110896	2180165	311452
WHITE HAKE	Value(\$)	261727	112661	65903	93744	63103	43608	-	640746	106791
	Weight(kg)	286105	126288	77202	104706	71872	52763	66421	785357	112194
CUSK	Value(\$)	72485	31930	26194	31663	22118	16252	-	200641	33440
	Weight(kg)	68897	33567	28346	32028	22964	16598	23883	226283	32326
CATFISH	Value(\$)	1273	379	579	649	1619	318	-	4818	803
	Weight(kg)	3585	1128	1530	1838	4321	899	905	14206	2029
LUMPFISH ROE	Value(\$)	699128	820085	1192346	159147	511694	377311	-	3759710	626618
	Weight(kg)	107844	126456	251836	72191	221208	171146	43052	993733	141962
MONKFISH	Value(\$)	3530	640	281	1427	626	621	-	7126	1188
	Weight(kg)	7798	1855	834	2131	686	995	994	15293	2185
HERRING	Value(\$)	-	973	-	-	-	2520	-	3493	582
	Weight(kg)	-	3700	-	-	-	9526	39826	53052	7579
MACKEREL	Value(\$)	-	-	2170	264	2014	1	-	4449	742
	Weight(kg)	-	-	2051	599	4568	1	-	7219	1031
SWORDFISH	Value(\$)	2172857	703926	508042	796526	703025	658143	-	5842519	923753
	Weight(kg)	255150	79916	58217	115275	99005	86858	99485	793926	113418
BIGEYE TUNA	Value(\$)	82865	13668	35519	67510	2999	35381	-	237941	39657
	Weight(kg)	13076	2093	5063	10625	442	4323	2105	37727	5390
BLUEFIN TUNA	Value(\$)	-	17745	5491	-	6406	-	-	29642	4940
	Weight(kg)	-	774	235	-	369	-	284	1662	237
YELLOWFIN TUNA	Value(\$)	38619	13717	15880	12268	-	16768	-	97252	16209
	Weight(kg)	7093	2357	3966	2032	-	2523	32	18003	2572
PORBEAGLE SHARK	Value(\$)	240311	16359	37691	24514	175122	329713	-	823709	137285
	Weight(kg)	103308	9260	17397	11258	118164	152300	198291	609978	87140
MACKEREL AND MAKO SHARK	Value(\$)	25713	9533	10453	5793	4608	7362	-	63462	10577
	Weight(kg)	13704	5800	6049	3251	2783	4384	3221	39192	5599
QUAHAUGS	Value(\$)	61254	51477	110462	207114	589194	114966	-	1134467	189078
	Weight(kg)	113150	84368	184429	343205	810478	200468	104335	1840433	262919
PROPELLOR CLAMS	Value(\$)	3804	9746	79296	1248	-	2931	-	97025	16171
	Weight(kg)	6976	44563	148701	313	56112	322494	817565	1396724	199532
ARCTIC SURF CLAMS	Value(\$)	11409580	20344050	17010064	21532623	22852549	17064253	-	110213119	18368853
	Weight(kg)	21665735	39257544	36701886	46245007	47801832	36352497	21077236	249101736	35585962
SEA SCALLOPS	Value(\$)	4633	-	-	554728	1617829	1600984	-	3778175	629696
	Weight(kg)	3524	-	-	421918	1230461	1217666	742309	3615878	516554
SQUID	Value(\$)	-	-	-	330	-	-	-	330	55
	Weight(kg)	-	-	-	300	-	-	3	303	43
ICELAND SCALLOPS	Value(\$)	7530	-	-	-	-	-	-	7530	1255
	Weight(kg)	5650	-	-	-	-	-	-	5650	807
SEA URCHINS	Value(\$)	-	16483	-	28039	15267	-	-	59788	9965
	Weight(kg)	-	4918	-	9617	5251	-	-	19786	2827
LOBSTER	Value(\$)	-	-	-	-	-	-	-	-	-
	Weight(kg)	-	-	-	-	-	-	360	360	51
SHRIMP	Value(\$)	4126524	4154756	3771600	3722972	2687240	3858914	-	22322007	3720335
	Weight(kg)	2096693	2180565	2319192	1983412	1529023	1791124	1230135	13130144	1875735
ROCK CRAB	Value(\$)	-	82	1759	1648	555	353	-	4397	733
	Weight(kg)	-	148	2376	1869	662	248	1680	6983	998
SNOW CRAB	Value(\$)	2307059	1837110	1764918	1417169	3315813	18342505	-	28984574	4830762
	Weight(kg)	298996	277777	340666	476169	955589	3486255	3710616	9546068	1363724
OTHER	Value(\$)	117667	38284	25072	45251	37866	35551	-	299691	49949
	Weight(kg)	64775	51235	21256	59394	17497	8923	12669	235749	33678
Total	Value(\$)	27034426	31199002	27547531	30857286	35379624	44482174	-	196500043	32750007
	Weight(kg)	22339262	26932156	27861086	31127045	35383544	30038444	23727900	197409437	28201348

Table 4d Catch by Species in NAFO Unit Area 3Psf

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	3904	742	7824	1150474	4129297	3945049	1949596	11186887	1598127
	Weight(kg)	3398	663	6268	1043082	3019678	2547613	1403638	8024340	1146334
HADDOCK	Value(\$)	3215	3217		13037	1247	2156	5440	28312	4045
	Weight(kg)	1750	2919		9045	1112	2343	5923	23092	3299
REDFISH	Value(\$)				611	32	170	36	850	121
	Weight(kg)				924	67	259	59	1309	187
ATLANTIC HALIBUT	Value(\$)	3784	13189		13343	1837	5124	10690	47968	6853
	Weight(kg)	689	2212		2196	322	868	2097	8384	1198
AMERICAN PLAICE	Value(\$)	141	9	410	6779	44722	427092079	4	115563	16509
	Weight(kg)	141	10	518	11979843	7	530302597	3	150088	21441
YELLOWTAIL FLOUNDER	Value(\$)				12097849	6	16334704	3	63969	9138
	Weight(kg)				242678457	6	204102078	1	100034	14291
WITCH FLOUNDER	Value(\$)				1	4	64	54	123	18
	Weight(kg)				3	9	77	63	152	22
WINTER FLOUNDER	Value(\$)		14		29				43	6
	Weight(kg)		16		48				64	9
GREENLAND HALIBUT	Value(\$)	1544			1	-	120	34	1699	243
	Weight(kg)	770			3	-	75	25	873	125
FLOUNDERS	Value(\$)	562				4	15		581	83
	Weight(kg)	1424				4	15		1443	206
SKATE	Value(\$)	5387	1435	1491	9404	15168	43400384	6	120132	17162
	Weight(kg)	14332	3936	3327	25697879	6	147189	167007	410284	58612
POLLOCK	Value(\$)	76	2661		1649	8229	125	817	13557	1937
	Weight(kg)	83	4140		3001	13535	218	1779	22756	3251
WHITE HAKE	Value(\$)	2875	2073		13549	5883	2076	15208	41664	5952
	Weight(kg)	2212	2519		22224	9649	4392	24292	65288	9327
CUSK	Value(\$)	29	14		214	21			278	40
	Weight(kg)	24	22		335	24			405	58
CATFISH	Value(\$)	15			17	103	345	107	587	84
	Weight(kg)	54			70	363	1252	251	1990	284
MONKFISH	Value(\$)	2177	5503		10972	597	748	13750	33747	4821
	Weight(kg)	3185	2995		6635	395	695	8396	22301	3186
BLUEFIN TUNA	Value(\$)						960462238	0	118426	16918
	Weight(kg)						9231	1393	10624	1518
PORBEAGLE SHARK	Value(\$)	183857	115200	73517	206078304	9	23670		459900	65700
	Weight(kg)	79305	52957334	7	106622813	3	10737		215141	30734
MACKEREL AND MAKO SHARK	Value(\$)				1648	327	290	12	2276	325
	Weight(kg)				2003	264	262	8	2537	362
SEA SCALLOPS	Value(\$)	267193	16016	9370	5055			512	298146	42592
	Weight(kg)	203019	12132	5305	3806			352	224614	32088
SQUID	Value(\$)				12				12	2
	Weight(kg)				36				36	5
ICELAND SCALLOPS	Value(\$)	228889	74895	2537520	299126	396683	145948	432015	4115076	587868
	Weight(kg)	170391	50003	1544352	187710	248923	91585	296029	2588993	369856
LOBSTER	Value(\$)	591							591	84
	Weight(kg)	58							58	8
SNOW CRAB	Value(\$)	5203400	3740933	4105257	5884780	12050284	16940238	13914554	61839447	8834207
	Weight(kg)	944099	1465106	2092665	3063545	3526407	3573921	3632499	18298242	2614035
OTHER	Value(\$)	39990	18799364	2	8	7979	3459	85	83960199	4
	Weight(kg)	2730	66	4122	252		79	283	7532	1076
Total	Value(\$)	5947629	3994702	6749030	7443414	16723961	21268085	16446971	78573793	11224828
	Weight(kg)	1427664	1599696	3689904	4417523	6990694	6464251	5590848	30180580	4311511

Table 4e Catch by Species in NAFO Unit Area 3Psg

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	9700	7511	20716	599305	1325308	246743	125539	2334821	333546
	Weight(kg)	7577	6500	17229	368512	819518	155762	120239	1495337	213620
HADDOCK	Value(\$)	5089	796	651	2646	3799	585	238	13804	1972
	Weight(kg)	2787	553	1143	1863	4169	556	4112	15183	2169
REDFISH	Value(\$)	3420	20	319718	953029	1029271	1489119	211933	4006509	572358
	Weight(kg)	12714	93	927630	2853011	3199686	4235637	440124	11668895	1666985
ATLANTIC HALIBUT	Value(\$)	171151	48093	137827	200842	164642	179001	12184	913740	130534
	Weight(kg)	23947	8236	25210	2998	6	22834	2318	5	21259
AMERICAN PLAICE	Value(\$)	17835	4386	13303	9104	15244	3722	1163	64757	9251
	Weight(kg)	20196	5969	17662	309	6	19481	4921	1834	83159
YELLOWTAIL FLOUNDER	Value(\$)	48			129	43	7912	1077	9209	1316
	Weight(kg)	116			314	108	10492	1332	12362	1766
WITCH FLOUNDER	Value(\$)	654	268	16176	774	1651	2253	619	22397	3200
	Weight(kg)	858	421	16243	1353	2968	2376	736	24955	3565
GREENLAND HALIBUT	Value(\$)	10312	401	1	51415	5425	12285	448	6	13457
	Weight(kg)	4486	27603	64195	4471	28961	595	4	14513	160183
FLOUNDERS	Value(\$)	1825		4048	895	6	1502	10	8286	1184
	Weight(kg)	2907		2296	597	8	1148	905	7861	1123
SKATE	Value(\$)	184007	62162	97846	285	3	87984	4957	36796	546605
	Weight(kg)	620657	189511	314792	254586	297729	17334	148805	1843414	263345
POLLOCK	Value(\$)	24		1137	490	19585	111	1	9832	42180
	Weight(kg)	19		1371	925	36772	669	1	21422	7720
WHITE HAKE	Value(\$)	10053	4162	2539	10472	21379	200	0	5589	66195
	Weight(kg)	11099	6740	3194	12674	36516	715	9	16988	104370
CUSK	Value(\$)	224	14	604	2129	2670	492	21	6155	879
	Weight(kg)	358	25	682	2903	2815	750	810	8343	1192
CATFISH	Value(\$)	27	113	3	1427	94	490	90	2244	321
	Weight(kg)	68	43	5	3126	340	1400	212	5194	742
MONKFISH	Value(\$)	6926	4896	18897	963	6	35569	1003	9653	96579
	Weight(kg)	8486	9352	19924	330	7	22449	1067	14715	8930
HERRING	Value(\$)					1				1
	Weight(kg)									0
SWORDFISH	Value(\$)	17728		1352			7490		26570	3796
	Weight(kg)	2174		159			1104		3437	491
PORBEAGLE SHARK	Value(\$)	41492	574	6	5022	9178	5703	125733	1498	234373
	Weight(kg)	18577	2097	1	2295	5189	3878	57495	882	109287
MACKEREL AND MAKO SHARK	Value(\$)	405	119	60	1030	1487	414	149	3664	523
	Weight(kg)	236	81	41	525	955	224	92	2154	308
SEA SCALLOPS	Value(\$)	241036	64656	14795	360			54637	375485	53641
	Weight(kg)	181971	49147	11252	270			39555	282195	40314
ICELAND SCALLOPS	Value(\$)	34578	230	0	2490657	765570	233106	38601	130780	3745592
	Weight(kg)	26571	3413	4	1563466	480419	146280	24223	89615	2364708
SNOW CRAB	Value(\$)	18393	7696	76301	2083	9	43228	2961	4	196070
	Weight(kg)	3337	3109	38888	107	7	12650	6248		75309
OTHER	Value(\$)	6460	11138	1763	2724	1746	3631	1259	28721	4103
	Weight(kg)	2071	4748	3605	3747	15196	3122	1964	34453	4922
Total	Value(\$)	781386	368088	3274832	2678858	3004800	2180861	616524	12905348	1843621
	Weight(kg)	951212	367236	3031282	4061951	4673313	4596848	940114	18621956	2660279

Table 4f Catch by species in NAFO Unit Area 3Psh

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	105985	95380	249980	3118694	3041811	5599344	2975222	15186415	2169488
	Weight(kg)	94361	100030	286167	3089566	2390791	4571618	2525559	13058092	1865442
HADDOCK	Value(\$)	34228	136119	56853	187138	74270	133396	94691	716696	102385
	Weight(kg)	35998	130803	63759	213120	91501	151011	91394	777586	111084
REDFISH	Value(\$)	65770	6882	77404	104802	134047	35707	89251	513863	73409
	Weight(kg)	243149	25001	142936	155092	229636	81577	170033	1047424	149632
ATLANTIC HALIBUT	Value(\$)	406430	228592	292522	615259	509681	515573	365739	2933796	419114
	Weight(kg)	55723	40807	493539	7519	72667	70422	166552	553043	79006
AMERICAN PLAICE	Value(\$)	3667	14373	276104	3564	67087	116595	299156	572051	81722
	Weight(kg)	5760	41667	790789	7826	150198	224681	332351	931561	133080
YELLOWTAIL FLOUNDER	Value(\$)	48			13144	18021	57297	103558	192069	27438
	Weight(kg)	115			26849	26293	102236	117873	273366	39052
WITCH FLOUNDER	Value(\$)	1153	39174	55535	107541	124216	71629	313118	712365	101766
	Weight(kg)	1816	82332	148357	258333	278940	145044	303054	1217876	173982
WINTER FLOUNDER	Value(\$)						80	53	133	19
	Weight(kg)						132	89	221	32
GREENLAND HALIBUT	Value(\$)	160049	61135	190172	240950	46626	118391	37127	854450	122064
	Weight(kg)	71579	32674	171265	98584	29672	93885	44395	542054	77436
FLOUNDERS	Value(\$)	39	356		3	7	3236	860	4502	643
	Weight(kg)	96	190		2	8	4849	1631	6776	968
SKATE	Value(\$)	176324	76580	95027	214842	159423	139740	227076	1089011	155573
	Weight(kg)	457842	214986	275042	792142	468591	483883	922190	3614676	516382
POLLOCK	Value(\$)	231646	146183	191029	193910	198627	51790	125383	1138568	162653
	Weight(kg)	226623	226345	351026	357288	364175	71533	271019	1868009	266858
WHITE HAKE	Value(\$)	284651	199582	107781	285704	264722	377941	209948	1730328	247190
	Weight(kg)	276286	256401	151520	407945	406693	698043	454390	2651278	378754
CUSK	Value(\$)	710	116	231	2496	2896	2580	259	9288	1327
	Weight(kg)	1043	174	259	2197	4639	2806	3328	14446	2064
CATFISH	Value(\$)	13	233	681	511	158	376	893	2866	409
	Weight(kg)	41	291	924	1973	531	1118	2630	7508	1073
LUMPFISH ROE	Value(\$)	2892	537	163	75				3667	524
	Weight(kg)	439	81	64	44				628	90
MONKFISH	Value(\$)	255390	147380	87423	147930	62014	40256	239402	979796	139971
	Weight(kg)	170423	94631	83673	111744	38374	24877	149909	673631	96233
SWORDFISH	Value(\$)	8506	6807	10415	3998	27269			56996	8142
	Weight(kg)	1062	779	1127	505	5184			8657	1237
BIGEYE TUNA	Value(\$)	39					6651		6689	956
	Weight(kg)	8					954		962	137
BLUEFIN TUNA	Value(\$)				42237	23954	11340	179871	257402	36772
	Weight(kg)				4059	2302	1090	11196	18647	2664
YELLOWFIN TUNA	Value(\$)	10							10	1
	Weight(kg)	3							3	0
PORBEAGLE SHARK	Value(\$)	132435	61119	66139	116756	104788	141456	15957	638649	91236
	Weight(kg)	57635	31582	299995	4346	71292	64164	9441	318459	45494
MACKEREL AND MAKO SHARK	Value(\$)	1319	1311	1411	1275	1990	2478	1108	10893	1556
	Weight(kg)	860	609	870	1133	1262	1404	776	6914	988
SEA SCALLOPS	Value(\$)	3450		825					4275	611
	Weight(kg)	2624		467					3091	442
ICELAND SCALLOPS	Value(\$)	2750	1144	24346	441	145			28825	4118
	Weight(kg)	2086	718	15276	276	91			18447	2635
CRAB, QUEEN-SNOW	Value(\$)	66310	33546		38457	77640	99913	72609	388475	55496
	Weight(kg)	11738	13554		20544	22721	21077	18820	108454	15493
OTHER	Value(\$)	27441	11753	15288	8475	15486	16472	3921	98836	14119
	Weight(kg)	19169	4274	10182	3754	1722	837	4806	44744	6392
Total	Value(\$)	1971257	1268300	1550834	5488128	4954879	7542241	5355202	28130840	4018691
	Weight(kg)	1736479	1297929	1861406	5794797	4657283	6817241	5601436	27766571	3966653

Table 4g Catch by species for NAFO Unit Area 4Vsb

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	6040	2837	1499	23939	9879	4316	-	58510	9752
	Weight(kg)	7700	3226	3199	19260	4243	2473	914	51015	7288
HADDOCK	Value(\$)	1013	235	101	715	2675	426	-	5165	861
	Weight(kg)	900	240	79	488	1474	230	3	3414	488
REDFISH	Value(\$)	31032	22606	7735	433	2860	44125	-	108791	18132
	Weight(kg)	58860	42276	18926	1108	7803	00862	216526	446361	63766
ATLANTIC HALIBUT	Value(\$)	10076	638	154	16226	4944	1902	-	53940	8990
	Weight(kg)	1798	127	24	2593	4346	251	-	9139	1306
AMERICAN PLAICE	Value(\$)	5952	3047	53423	66524	119374	66738	-	315059	52510
	Weight(kg)	4347	2414	32312	59221	120341	60544	11158	290337	41477
YELLOWTAIL FLOUNDER	Value(\$)	-	489	-	-	753	-	-	1242	207
	Weight(kg)	-	420	-	-	759	-	-	1179	168
WITCH FLOUNDER	Value(\$)	12880	5945	2539	5385	1302	3972	-	32021	5337
	Weight(kg)	5564	4305	1537	3320	908	2586	94	18314	2616
WINTER FLOUNDER	Value(\$)	-	5	-	-	-	-	-	5	1
	Weight(kg)	-	5	-	-	-	-	-	5	1
GREENLAND HALIBUT	Value(\$)	186	66	187	326	364	10505	-	11633	1939
	Weight(kg)	202	40	169	246	344	9587	2400	12988	1855
FLOUNDERS	Value(\$)	12888	29030	30974	5738	18179	73261	-	170070	28345
	Weight(kg)	6280	18737	17594	5136	20613	55389	29992	153741	21963
SKATE	Value(\$)	35	967	521	-	73	-	-	1596	266
	Weight(kg)	57	2924	1575	-	221	-	9914	14691	2099
POLLOCK	Value(\$)	18495	19471	651	40	662	65	-	39384	6564
	Weight(kg)	32011	30429	988	55	1109	144	19	64755	9251
WHITE HAKE	Value(\$)	541	80	10	9217	4651	269	-	14767	2461
	Weight(kg)	1895	235	12	12879	6438	266	306	22031	3147
CUSK	Value(\$)	10	-	-	14	52	3	-	80	13
	Weight(kg)	26	-	1	23	83	0	-	133	19
CATFISH	Value(\$)	34	17	6	13	63	27	-	159	27
	Weight(kg)	88	55	22	41	133	61	-	400	57
MONKFISH	Value(\$)	263	173	6	222	-	31	-	694	116
	Weight(kg)	447	318	2	356	-	48	211	1382	197
HERRING	Value(\$)	-	-	-	-	-	2520	-	2520	420
	Weight(kg)	-	-	-	-	-	9526	680	10206	1458
SWORDFISH	Value(\$)	-	-	2046	-	-	-	-	2046	341
	Weight(kg)	-	-	243	-	-	-	-	243	35
BLUEFIN TUNA	Value(\$)	-	17745	-	-	6406	-	-	24151	4025
	Weight(kg)	-	774	-	-	369	-	-	1143	163
PORBEAGLE SHARK	Value(\$)	4067	7148	11725	3111	-	26351	-	52401	8734
	Weight(kg)	1845	3242	5318	1411	-	11953	-	23769	3396
MACKEREL AND MAKO SHARK	Value(\$)	29	-	131	160	8	-	-	328	55
	Weight(kg)	19	-	57	117	4	-	-	197	28
QUAHAUGS	Value(\$)	-	-	-	-	1170	-	-	1170	195
	Weight(kg)	-	-	-	-	2144	-	-	2144	306
ARCTIC SURF CLAMS	Value(\$)	-	3511	14078	9232	4813	14984	-	46618	7770
	Weight(kg)	-	3981	17050	10281	4872	15856	-	52040	7434
SEA SCALLOPS	Value(\$)	4633	-	-	-	-	-	-	4633	772
	Weight(kg)	3524	-	-	-	-	-	-	3524	503
ICELAND SCALLOPS	Value(\$)	7530	-	-	-	-	-	-	7530	1255
	Weight(kg)	5650	-	-	-	-	-	-	5650	807
SEA URCHINS	Value(\$)	-	-	-	1548	-	-	-	1548	258
	Weight(kg)	-	-	-	585	-	-	-	585	84
SHRIMP	Value(\$)	93481	176448	166224	376382	381946	272544	-	1467026	244504
	Weight(kg)	44634	91899	101705	210550	216562	123625	360	789335	112762
LOBSTER	Value(\$)	-	-	-	-	-	-	-	-	-
	Weight(kg)	-	-	-	-	-	-	133208	-	-
ROCK CRAB	Value(\$)	-	82	-	-	-	-	-	82	14
	Weight(kg)	-	148	-	-	-	-	1526	1674	239
SNOW CRAB	Value(\$)	1874543	1762695	1569006	953481	2389117	10647433	-	19196273	3199379
	Weight(kg)	242942	266524	302848	320372	689020	2069763	1660169	5551638	793091
OTHER	Value(\$)	1209	2301	1281	634	-	606	-	6032	1005
	Weight(kg)	517	10	344	297	-	84	0	1252	179
Total	Value(\$)	2084937	2055537	1862806	1473337	2979290	11170076	-	21625984	3604331
	Weight(kg)	419306	472329	504005	648339	1091824	2463248	2067509	7666560	1095223

Table 4h Catch by species for NAFO Unit Area 4Vsc

Species		1995	1996	1997	1998	1999	2000	2001	Total	Average
COD	Value(\$)	123 103	828 21	896 70	106 797	138 432	102 228	-	643 051	107 175
	Weight(kg)	150 854	110 063	828 89	796 85	114 537	805 07	733 894	91 924	988 46
HADDOCK	Value(\$)	549 46	366 15	243 55	203 48	294 39	256 55	-	191 358	318 93
	Weight(kg)	444 13	298 77	161 23	125 52	227 36	189 59	214 51	66 111	237 30
REDFISH	Value(\$)	128 8354	439 636	535 651	149 427	738 996	411 465	-	356 3529	593 921
	Weight(kg)	418 4592	154 5978	200 1727	530 759	240 0551	128 2655	361 5881	155 62143	222 3163
ATLANTIC HALIBUT	Value(\$)	752 212	802 067	125 5003	754 182	853 446	738 617	-	515 5528	859 255
	Weight(kg)	100 232	125 768	168 022	105 945	108 341	916 47	167 715	867 670	123 953
AMERICAN PLAICE	Value(\$)	265 544	543 964	614 313	531 077	409 875	272 890	-	263 7663	439 611
	Weight(kg)	197 649	372 490	371 939	496 600	414 610	247 620	132 231	223 3139	319 020
YELLOWTAIL FLOUNDER	Value(\$)	955 485	495 415	669 79	373 21	415 97	7273	-	160 4069	267 345
	Weight(kg)	730 335	388 339	759 83	317 72	419 27	5499	7667	28 1522	183 075
WITCH FLOUNDER	Value(\$)	110 491	498 00	810 04	388 13	179 02	8001	-	306 010	510 02
	Weight(kg)	483 35	310 32	557 25	302 86	161 90	5413	5772	192 753	275 36
WINTER FLOUNDER	Value(\$)	14	5	3237			115 59		148 14	2469
	Weight(kg)	28	4	1958			7490		9480	1354
GREENLAND HALIBUT	Value(\$)	2314	3096	3086	3327	5881	7226	-	24930	4155
	Weight(kg)	3294	3922	3759	2841	10227	6951	10751	41745	5964
FLOUNDERS	Value(\$)	947 895	507 432	805 706	208 633	277 122	221 018	-	296 7805	494 634
	Weight(kg)	621 331	319 202	474 263	195 647	314 248	167 136	138 938	223 0765	318 681
SKATE	Value(\$)	814 386	476 007	299 778	142 070	166 506	117 173	-	201 5922	335 987
	Weight(kg)	150 5918	136 7636	909 264	394 294	465 737	366 326	236 038	524 5213	749 316
POLLOCK	Value(\$)	228 773	174 327	273 39	956 12	252 279	181 387	-	959 718	159 953
	Weight(kg)	572 677	390 896	432 87	137 322	414 290	234 555	107 805	190 0832	271 547
WHITE HAKE	Value(\$)	154 705	865 00	509 53	820 72	447 14	422 63	-	461 208	768 68
	Weight(kg)	181 633	101 458	626 54	888 90	537 29	513 95	637 084	403 467	862 10
CUSK	Value(\$)	440 95	270 71	218 19	289 40	191 45	158 64	-	156 934	261 56
	Weight(kg)	417 62	286 38	239 93	294 53	201 77	162 14	233 15	83 552	262 22
CATFISH	Value(\$)	799	271	351	424	645	271	-	2762	460
	Weight(kg)	2522	826	946	1181	1614	776	607	8472	1210
LUMPFISH	Value(\$)		1						1	0
	Weight(kg)		64						64	9
MONKFISH	Value(\$)	2785	379	227	1092	59	590	-	5134	856
	Weight(kg)	6413	1404	730	1534	107	947	750	11885	1698
HERRING	Value(\$)					-		-		
	Weight(kg)					-		391 46	391 46	5592
MACKEREL	Value(\$)						1		1	0
	Weight(kg)						1		1	0
SWORDFISH	Value(\$)	172 8077	588 425	464 841	642 742	702 596	573 359	-	470 0041	783 340
	Weight(kg)	204 755	667 33	532 13	933 05	989 42	782 75	993 034	494 526	992 18
BIGEYE TUNA	Value(\$)	145 96	1766	6477	872	2622	1093	-	27425	4571
	Weight(kg)	2117	271	907	135	389	188	2105	6112	873
BLUEFIN TUNA	Value(\$)			549 1				-	549 1	915
	Weight(kg)			235				284	519	74
YELLOWFIN TUNA	Value(\$)	1772	5	3382	149				5309	885
	Weight(kg)	354	2	791	22				1169	167
PORBEAGLE SHARK	Value(\$)	1996 41	698 5	255 37	21403	175 122	303 182	-	731 870	121 978
	Weight(kg)	867 96	4771	11846	9847	118 164	140 245	534 723	425 141	607 34
MACKEREL AND MAKO SHARK	Value(\$)	188 47	7774	6957	2247	4563	4791	-	451 78	7530
	Weight(kg)	103 12	471 5	3878	1211	2759	3082	3176	291 33	4162
QUAHAUGS	Value(\$)	612 54	514 77	110 462	207 114	587 533	114 966	-	113 2805	188 801
	Weight(kg)	113 150	843 68	184 429	343 205	807 433	200 468	104 335	183 7388	262 484
PROPELLOR CLAMS	Value(\$)	3804	9746	792 96	1248	-	293 1	-	97025	161 71
	Weight(kg)	6976	445 63	148 701	313	561 12	322 494	817 565	139 6724	199 532
ARCTIC SURF CLAMS	Value(\$)	1140 9580	203 40539	1699 5477	215 23391	2284 2077	170 49269	-	1101 60333	183 60055
	Weight(kg)	1055 7747	191 34142	2020 3074	253 68095	258 35038	198 95735	117 70379	132 764210	189 66316
SEA SCALLOPS	Value(\$)				554 728	161 7829	160 0984	-	377 3541	628 924
	Weight(kg)				421 918	123 0461	121 7666	742 309	361 2354	516 051
SQUID	Value(\$)							-		
	Weight(kg)							3	3	0
SEA URCHINS	Value(\$)				1157				1157	193
	Weight(kg)				437				437	62
SHRIMP	Value(\$)	391 2888	376 1664	324 3953	333 3826	2174 146	358 4660	-	200 11137	333 5190
	Weight(kg)	197 3296	196 9671	199 2808	176 3768	123 2733	166 6723	109 6927	116 95926	167 0847
SNOW CRAB	Value(\$)	146 174	664 50	917 32	377 694	771 461	769 5073	-	914 8585	152 4764
	Weight(kg)	189 45	100 49	177 08	126 904	221 319	141 6492	205 0447	386 1864	551 695
OTHER	Value(\$)	490 52	380 1	131 31	337 09	367 92	299 27	-	166 412	277 35
	Weight(kg)	312 62	728 9	169 21	515 88	151 04	6592	126 371	41 393	201 99
Total	Value(\$)	232 91585	285 64038	249 26210	289 00414	319 10782	331 23716	153 36055	170 716745	284 52791
	Weight(kg)	213 97698	261 44171	269 27773	303 19509	340 17475	275 32051	213 98106	187 736783	268 19540

Table 5 Frequency of Gear Type Used

	1995	1996	1997	1998	1999	2000	2001
NAFO 3Ps Division - Fixed Gear							
Beach and Bar Seine	4	4	4		17	4	9
Gill Net (Set or Fixed)	523	512	887	1668	3889	3324	2995
Longline	219	120	231	496	674	766	935
Hand Line (Baited)	1	2	28	45	42	72	529
Dip Net						16	3
Trap		1	85	7	16	7	12
Pot	680	768	908	1259	7476	7019	1577
Mechanized Squid Jigger		1					
Subtotal	1427	1408	2143	3475	12114	11208	6060
NAFO 3Ps Division - Mobile Gear							
Bottom Otter Trawl (Stern)	491	310	315	1268	472	1073	1329
Midwater Trawl (Stern)	81	446	314	382	988	511	110
Midwater Trawl (Side)			6	10		4	
Shrimp Trawl	2	17		33	122	99	
Danish Seine	182	35	29	19	44	43	36
Scottish Seine				7	216	357	174
Purse Seine	8	2	17	20	12	15	20
Dredge (Boat)	265	92	62	1304	657	649	219
Subtotal	1029	902	743	3043	2511	2751	1888
Total	2456	2310	2886	6518	14625	13959	7948
NAFO 4Vn Division - Fixed Gear							
Gill Net (Set or Fixed)			11	264	706	388	253
Gill Net (Drift)			18	6	13	4	
Longline	62	103	213	293	380	331	300
Hand Line (Baited)			70	62	136	32	89
Trap						72	39
Pot	1550	1204	930	754	2502	2592	2752
Jigger						1	
Subtotal	1612	1307	1242	1379	3737	3420	3433
NAFO 4Vn Division - Mobile Gear							
Bottom Otter Trawl (Stern)	556	257	217	261	404	320	181
Bottom Otter Trawl (Side)	8	6			2		
Midwater Trawl (Stern)	127		1	15	2	3	
Shrimp Trawl	55	6	90	80	75	39	66
Danish Seine	437	366	411	585	531	237	258
Scottish Seine	19	37	6	9	4	3	2
Purse Seine	72	59	68	2			1
Dredge (Boat)			1		16		
Diving				27	68	62	19
Harpoon		6	2		1		
Subtotal	1274	737	796	979	1103	664	527
Total	2886	2044	2038	2358	4840	4084	3960
NAFO 4Vs Division - Fixed Gear							
Gill Net (Set or Fixed)	6	6	9	9	34	1	10
Longline	886	570	481	480	567	442	560
Hand Line (Baited)	6	14	4	3	8		
Dip Net					1		
Pot	173	185	229	185	442	1266	1268
Subtotal	1071	775	723	677	1052	1709	1838

Table 6 Frequency of Vessel Sizes

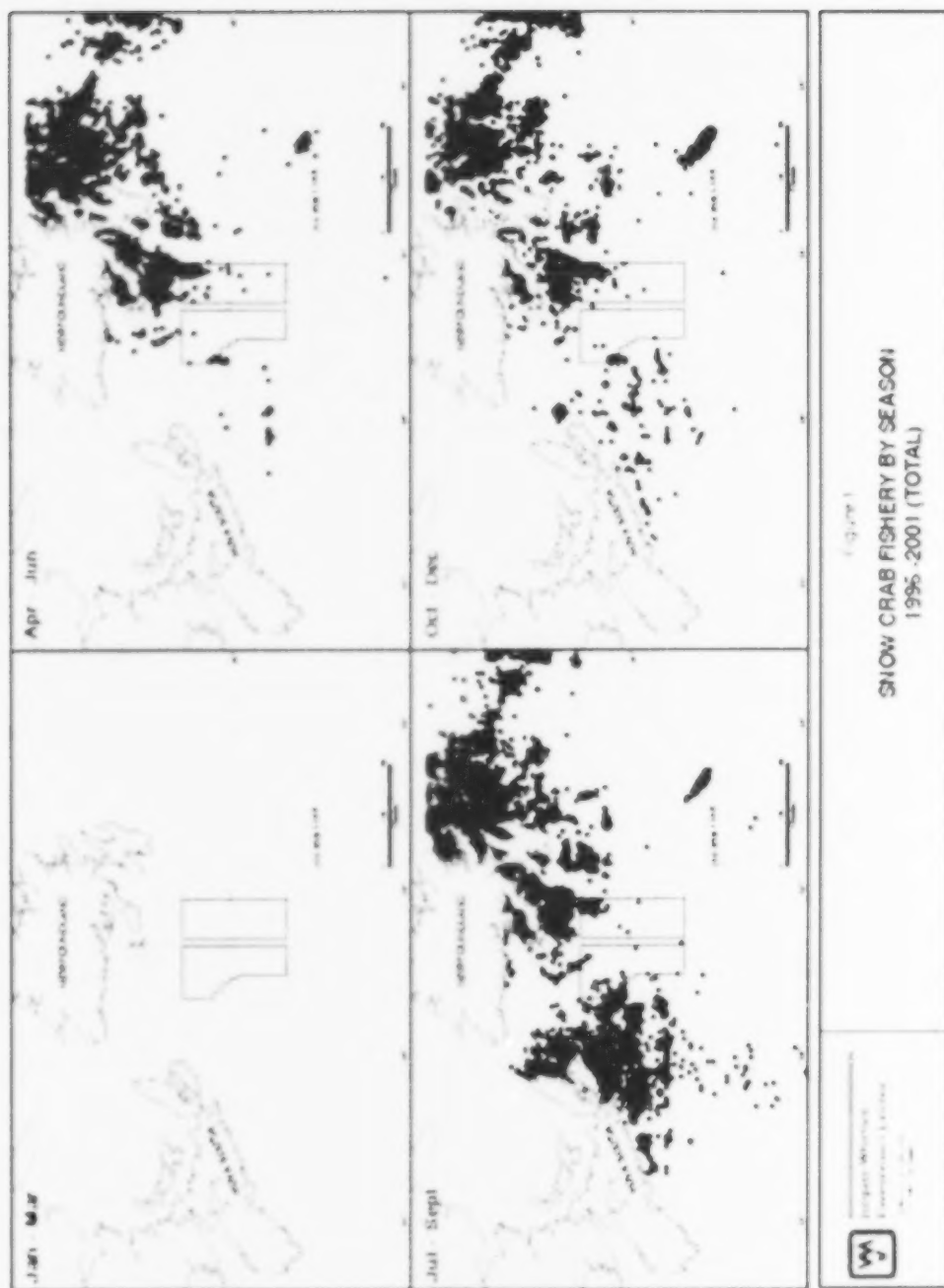
	1995	1996	1997	1998	1999	2000	2001
NAFO 3Ps Division							
1-34.9 FT	266	204	305	454	6256	5451	11
35-44.9 FT	527	808	1352	3021	5434	5444	99
45-64.9 FT	586	462	604	1245	1080	911	64
65-99.9 FT	361	103	83	357	416	288	130
100-124.9 FT	203	148	71	274	170	244	188
125 FT OR MORE	513	585	471	1167	1269	1621	154
Missing	0	0	0	0	0	0	7361
Total	2456	2310	2886	6518	14625	13959	8007
NAFO 4Vn Division							
NOT APPLICABLE	0	0	0	0	295	221	119
1-34.9 FT	906	602	589	790	2450	2164	2047
35-44.9 FT	1197	1104	1057	1198	1785	1350	1485
45-64.9 FT	234	222	218	241	305	233	202
65-99.9 FT	94	36	58	56	51	35	50
100-124.9 FT	194	66	82	8	80	55	43
125 FT OR MORE	261	14	34	65	43	26	12
Missing	0	0	0	0	0	0	2
Total	2886	2044	2038	2358	5009	4084	3960
NAFO 4Vs Division							
1-34.9 FT	46	73	58	26	141	57	46
35-44.9 FT	876	661	674	631	730	1279	1329
45-64.9 FT	856	668	479	349	355	592	580
65-99.9 FT	448	234	255	173	170	161	194
100-124.9 FT	200	198	319	400	566	453	267
125 FT OR MORE	913	781	753	1890	2264	1112	450
Missing	0	0	0	0	0	0	1148
Total	3339	2615	2538	3469	4226	3654	4014
NAFO 3Psf Unit Area							
1-34.9 FT	26	88	148	208	114	31	0
35-44.9 FT	123	263	296	533	960	1480	11
45-64.9 FT	50	48	61	183	332	261	0
65-99.9 FT	13	1	0	16	43	6	0
100-124.9 FT	69	14	1	11	4	0	1
125 FT OR MORE	19	2	12	88	246	144	0
Missing	0	0	0	0	0	0	1703
Total	300	416	518	1039	1699	1922	1715
NAFO 3Psg Unit Area							
35-44.9 FT	2	2	21	30	236	50	2
45-64.9 FT	57	38	71	207	104	31	8
65-99.9 FT	36	6	25	34	12	35	23
100-124.9 FT	48	23	59	96	33	69	31
125 FT OR MORE	38	5	43	160	315	425	22
Missing	0	0	0	0	0	0	178
Total	181	74	219	527	700	610	264
NAFO 3Psh Unit Area							
1-34.9 FT	1	1	0	0	4	20	0
35-44.9 FT	31	140	112	192	133	151	6
45-64.9 FT	233	159	281	223	95	189	40
65-99.9 FT	283	96	43	306	359	220	87
100-124.9 FT	4	2	5	80	80	104	80
125 FT OR MORE	38	77	86	482	430	581	26
Missing	0	0	0	0	0	0	1309
Total	590	475	527	1283	1101	1265	1548
NAFO 4Vsb Unit Area							
1-34.9 FT	43	40	35	19	34	41	33
35-44.9 FT	141	132	196	154	306	651	502
45-64.9 FT	22	14	11	45	70	150	74
65-99.9 FT	9	3	1	1	6	7	13
100-124.9 FT	16	14	33	58	113	77	56
125 FT OR MORE	20	13	8	12	6	7	4
Missing	0	0	0	0	0	0	1
Total	251	216	284	289	535	933	683
NAFO 4Vsc Unit Area							
1-34.9 FT	3	2	2	0	0	0	1
35-44.9 FT	660	489	461	428	389	593	819
45-64.9 FT	819	627	452	292	275	431	498
65-99.9 FT	383	218	245	172	164	149	181
100-124.9 FT	184	184	285	340	452	375	195
125 FT OR MORE	888	768	743	1878	2255	1105	410
Missing	0	0	0	0	0	0	1147
Total	2937	2288	2188	3110	3535	2653	3251

	1995	1996	1997	1998	1999	2000	2001
NAFO 4Vs Division - Mobile Gear							
Bottom Otter Trawl (Stern)	1041	607	477	324	584	512	733
Bottom Otter Trawl (Side)	1	4	7	4			
Midwater Trawl (Stern)	1	63	4	1	167	10	1
Shrimp Trawl	699	506	574	426	293	300	227
Danish Seine	263	191	253	197	140	31	48
Scottish Seine	2	8					
Troll Lines		1					1
Dredge (Boat)	261	459	499	1838	1984	1091	1165
Diving				2	6		
Harpoon		1	1			1	1
Subtotal	2268	1840	1815	2792	3174	1945	2176
Total	3339	2615	2538	3469	4226	3654	4014
NAFO 3Psf Unit Area - Fixed Gear							
Gill Net (Set or Fixed)	5	8	3	91	254	615	320
Gill Net (Drift)							
Longline	27	11	11	15	30	21	40
Hand Line (Baited)			2		1		6
Dip Net						16	1
Pot	197	389	497	757	1009	1044	1121
Subtotal	229	408	513	863	1294	1696	1488
NAFO 3Psf Unit Area - Mobile Gear							
Bottom Otter Trawl (Stern)		1	5	88	47	74	71
Midwater Trawl (Stern)					117		
Shrimp Trawl		1			30		
Danish Seine				3			
Scottish Seine				5	125	124	72
Dredge (Boat)	71	5		80	86	28	84
Subtotal	71	7	5	176	405	226	227
Total	300	415	518	1039	1699	1922	1715
NAFO 3Psg Unit Area - Fixed Gear							
Gill Net (Set or Fixed)	5	15	58	43	243	27	28
Longline	38	13	10	47	31	76	59
Hand Line (Baited)					2		
Trap						1	
Pot	1	4	7	3	3	2	
Subtotal	44	32	75	93	279	106	87
NAFO 3Psg Unit Area - Mobile Gear							
Bottom Otter Trawl (Stern)	58	21	68	127	137	158	156
Midwater Trawl (Stern)	1	1	19	110	230	326	2
Midwater Trawl (Side)			3	2			
Shrimp Trawl		2					
Danish Seine	2		3				
Dredge (Boat)	76	18	51	195	54	20	19
Subtotal	137	42	144	434	421	504	177
Total	181	74	219	527	700	610	264
NAFO 3Psh Unit Area - Fixed Gear							
Gill Net (Set or Fixed)	414	330	357	360	240	294	402
Longline	106	63	53	150	203	264	267
Hand Line (Baited)				11	1	1	15
Dip Net							1
Pot	3	1		3	8	22	3

	1995	1996	1997	1998	1999	2000	2001
Subtotal	523	394	410	524	452	581	688
NAFO 3Psh Unit Area - Mobile Gear							
Bottom Otter Trawl (Stern)	64	79	114	758	93	419	757
Midwater Trawl (Stern)	2		3		464	34	1
Shrimp Trawl		2					
Danish Seine						1	
Scottish Seine					91	230	102
Dredge (Boat)	1			1	1		
Subtotal	67	81	117	759	649	684	860
Total	590	475	527	1283	1101	1265	1548
NAFO 4Vb Unit Area - Fixed Gear							
Gill Net (Set or Fixed)						1	1
Longline	5	4	7	24	17	3	1
Dip Net					1		
Pot	163	147	194	142	334	775	564
Subtotal	168	151	201	166	352	779	566
NAFO 4Vb Unit Area - Mobile Gear							
Bottom Otter Trawl (Stern)	52	27	14	47	101	127	89
Bottom Otter Trawl (Side)	1	1					
Shrimp Trawl	13	18	31	45	44	22	18
Danish Seine	14	16	36	39	37	4	10
Scottish Seine	2	1					
Troll Lines		1					
Dredge (Boat)	1	1	2	1	1	1	
Diving				1			
Subtotal	83	65	83	133	183	154	117
Total	251	216	284	299	535	933	683
NAFO 4Vc Unit Area - Fixed Gear							
Gill Net (Set or Fixed)	5	4	4	4			6
Longline	736	490	432	395	468	383	508
Hand Line (Baited)	6	13	4	3	1		
Pot	9	8	21	41	84	482	701
Subtotal	756	515	461	443	553	865	1215
NAFO 4Vc Unit Area - Mobile Gear							
Bottom Otter Trawl (Stern)	985	579	462	287	481	383	622
Bottom Otter Trawl (Side)		3	7	4			
Midwater Trawl (Stern)	1	63	4	1	167	10	1
Shrimp Trawl	686	486	540	381	249	278	209
Danish Seine	249	175	216	156	103	27	38
Scottish Seine		7					
Troll Lines							1
Dredge (Boat)	260	458	497	1837	1982	1090	1165
Diving				1			
Harpoon			1				
Subtotal	2181	1771	1727	2667	2982	1788	2036
Total	2937	2286	2188	3110	3535	2653	3251

Table 7 Catch by Species for St. Pierre et Miquelon in NAFO Division 3Ps (1995 - 2001)

Species	Subdivision	1995	1996	1997	1998	1999	2000	2001
American Angler	3PS	-	-	-	1	-	-	1
American Lobster	3PS	-	-	1	-	1	-	2
American Plaice	3PS	-	-	23	16	24	40	112
Atlantic Cod	3PS	59	43	1,547	3,122	3,171	4,677	2350
Atlantic Halibut	3PS	-	-	-	-	1	-	1
Atlantic Herring	3PS	-	-	-	-	2	-	-
Atlantic Mackerel	3PS	-	-	1	3	1	26	-
Atlantic Redfishes (Ns)	3PS	-	-	292	373	419	194	129
Atlantic Salmon	3PS	-	1	1	1	1	1	1
Chars	3PS	-	-	-	-	-	-	1
Blue Mussel	3PS	9	3	2	4	-	9	-
Capelin	3PS	1	-	1	-	2	-	-
Greenland Halibut	3PS	-	-	7	13	6	2	7
Groundfishes (Ns)	3PS	-	-	-	16	-	-	-
Haddock	3PS	-	-	9	27	16	9	78
Icelandic Scallop	3PS	2	221	239	5	-	2	16
Large Sharks (Ns)	3PS	4	-	-	-	-	-	-
Lumpfish (Lumpsucker)	3PS	226	218	363	249	422	536	146
Mackerel	3PS	-	-	-	-	-	-	7
Marine Invertebrates (Ns)	3PS	-	-	-	45	-	-	-
Marine Molluscs (Ns)	3PS	-	1	32	-	17	205	115
Northern Bluefin Tuna	3PS	-	-	-	-	1	-	-
Pollock (Saithe)	3PS	-	-	14	13	6	37	13
Porbeagle	3PS	-	39	13	20	-	13	2
Snow Crab	3PS	1	189	368	354	589	511	498
Scallop (Ns)	3PS	-	-	-	-	-	-	2
Sea Scallop	3PS	3	23	27	3	-	-	-
Shortfin Squid	3PS	-	-	6	-	-	-	-
Skates (Ns)	3PS	4	2	3	6	4	21	38
White Hake	3PS	-	-	-	1	9	134	10
Witch Flounder	3PS	-	-	7	43	33	7	120
Wolffishes (Ns)	3PS	-	-	-	3	2	-	1
Yellowtail Flounder	3PS	-	-	18	59	33	6	152
Total		309	740	2974	4377	4760	6430	3802



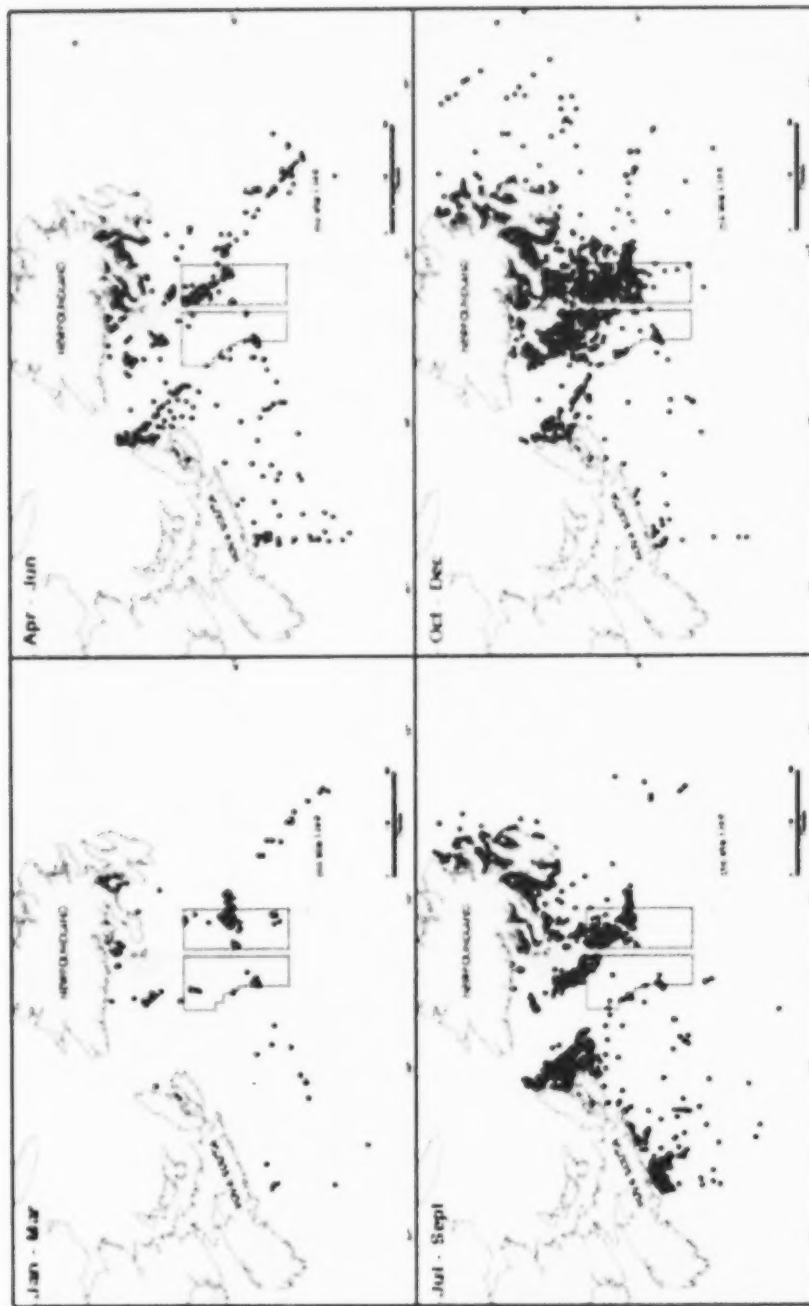
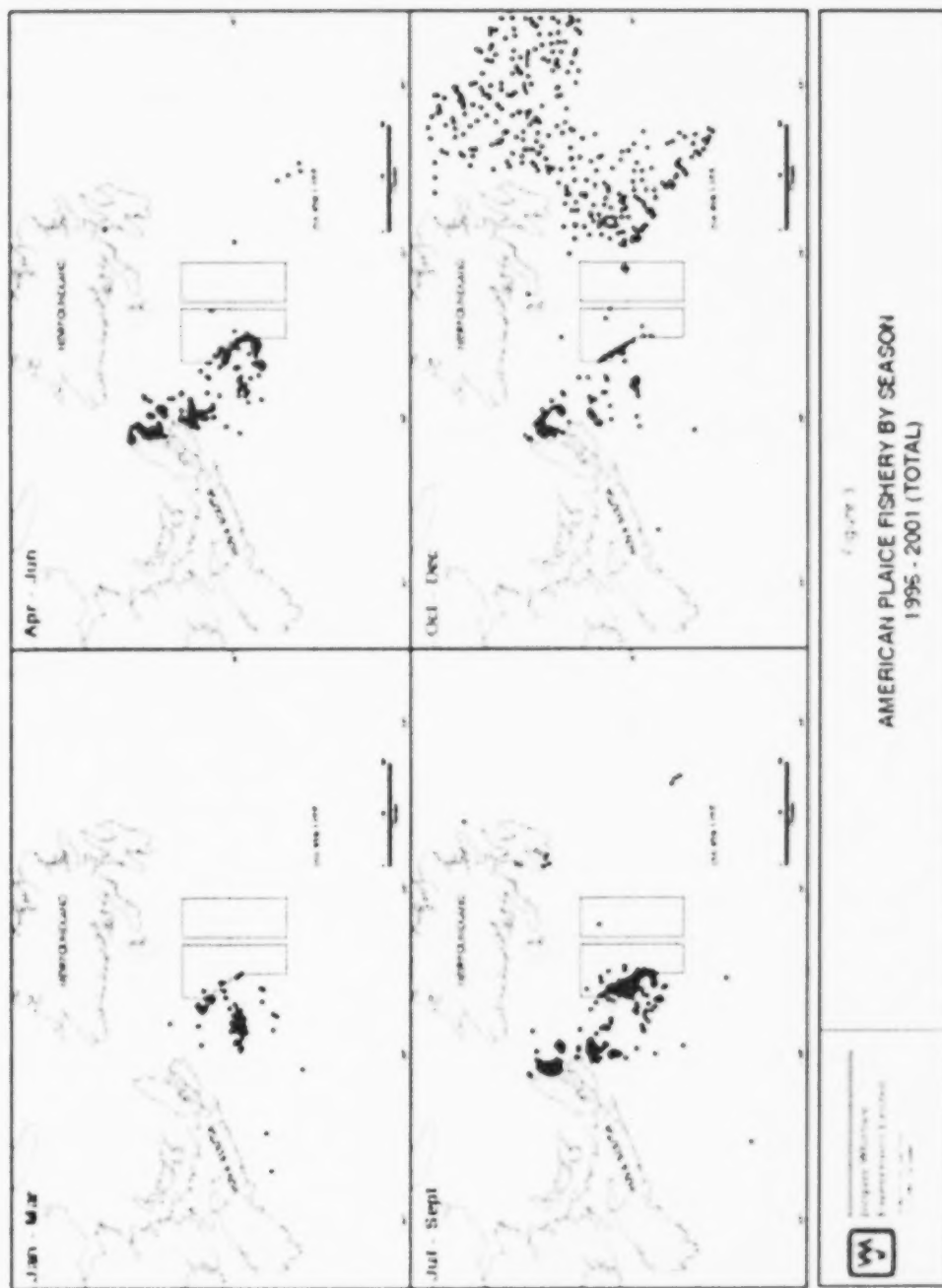


Figure 2
COD FISHERY BY SEASON
1995 - 2001 (TOTAL)



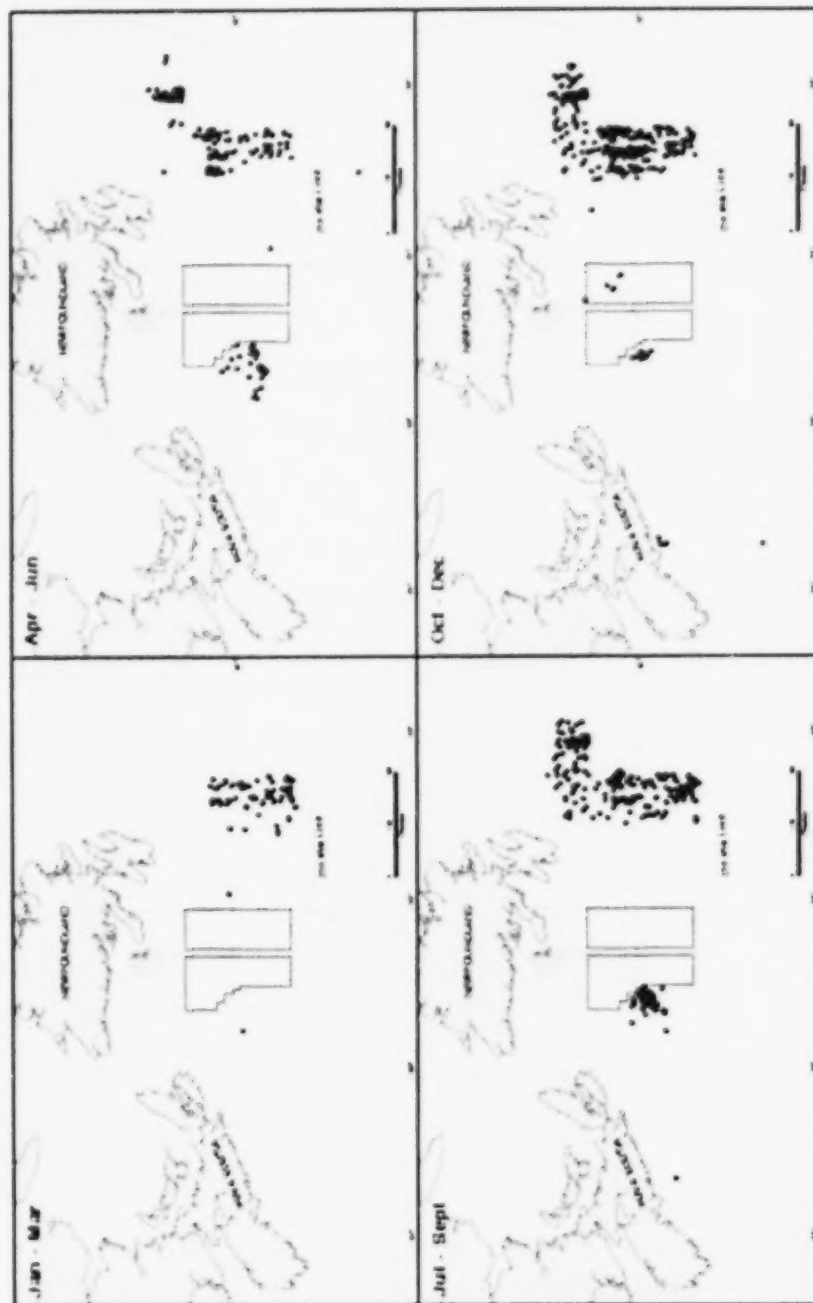
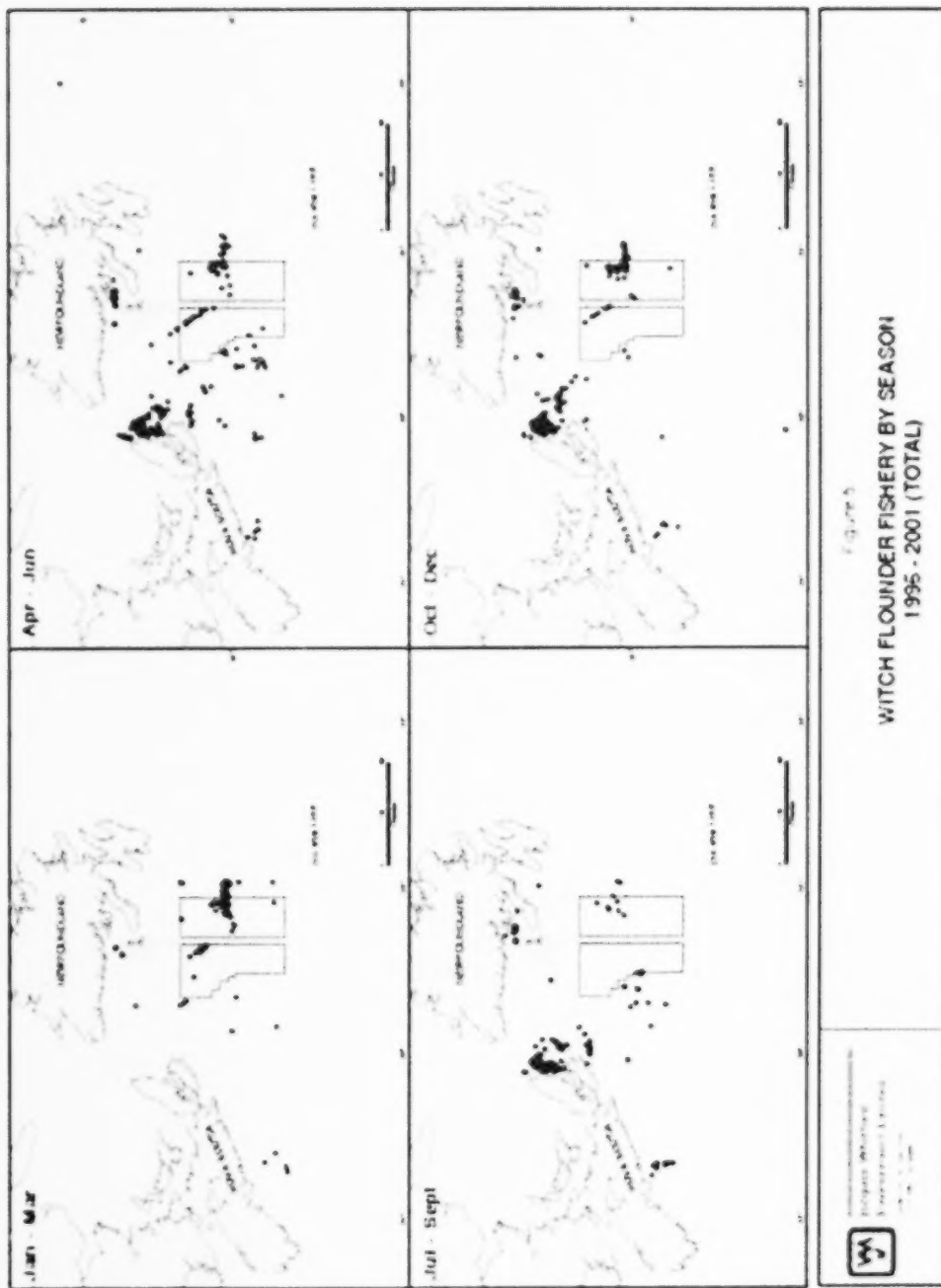
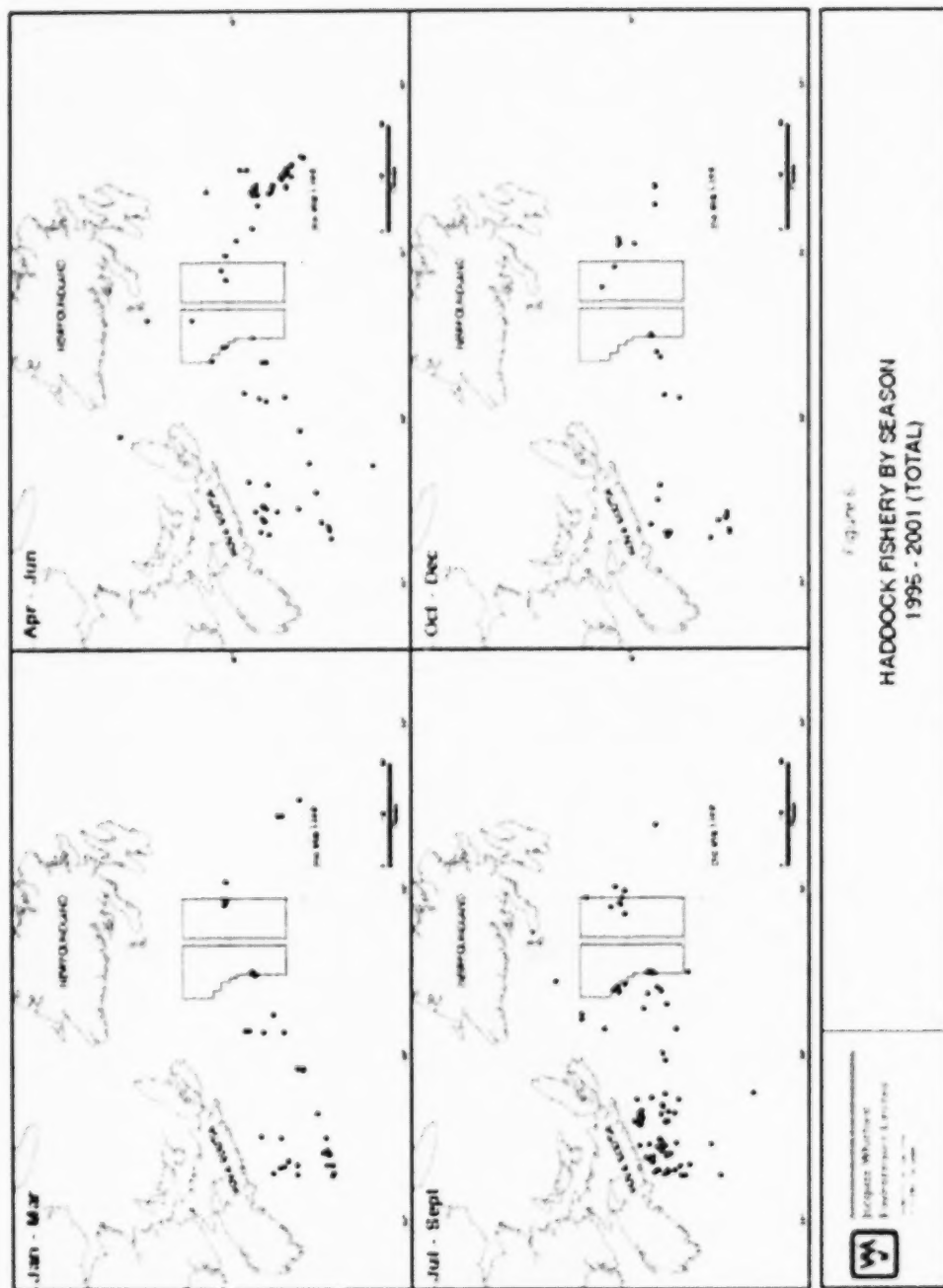
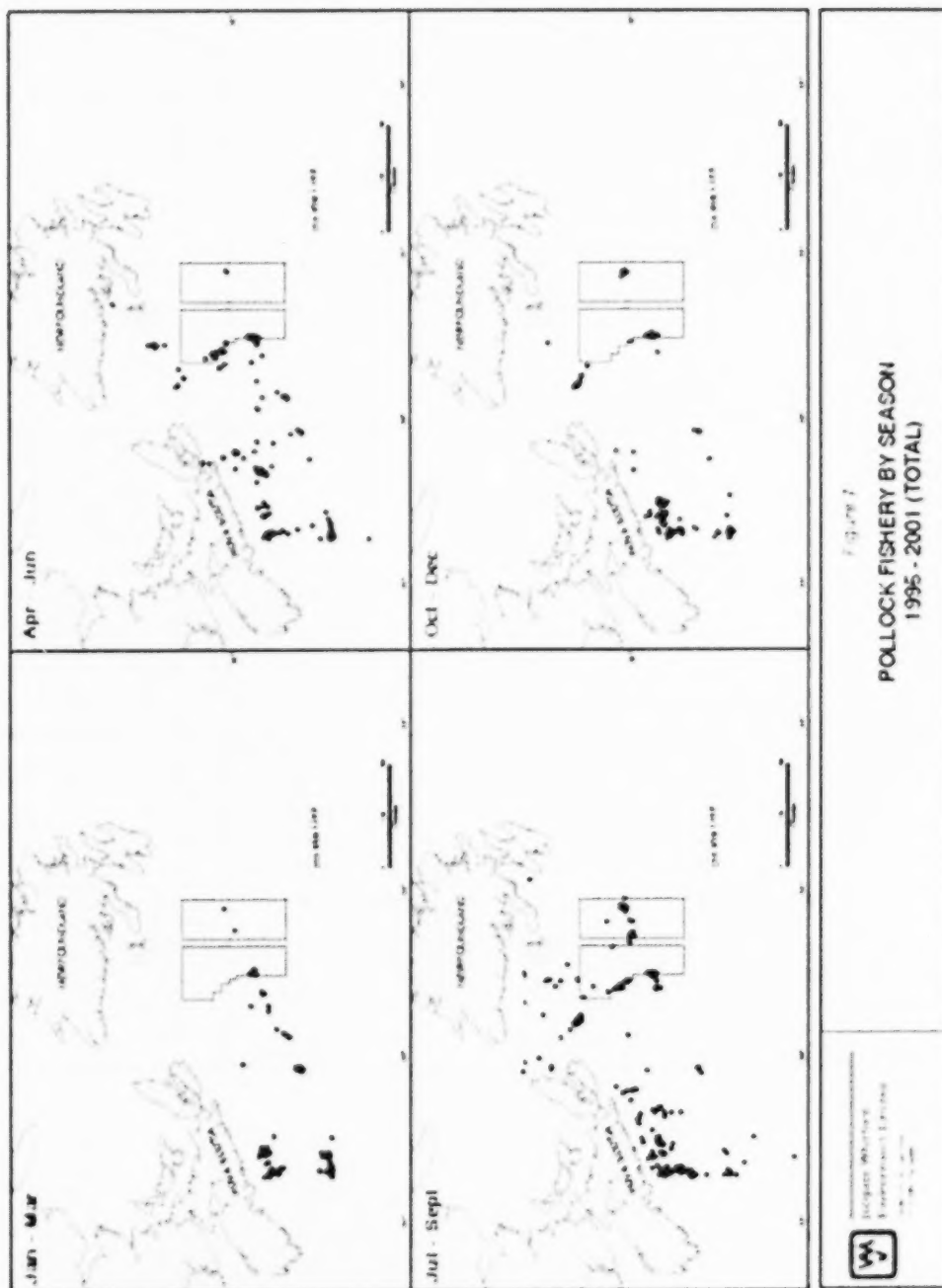


Figure 4
YELLOWTAIL FLOUNDER FISHERY BY SEASON
1995 - 2001 (TOTAL)







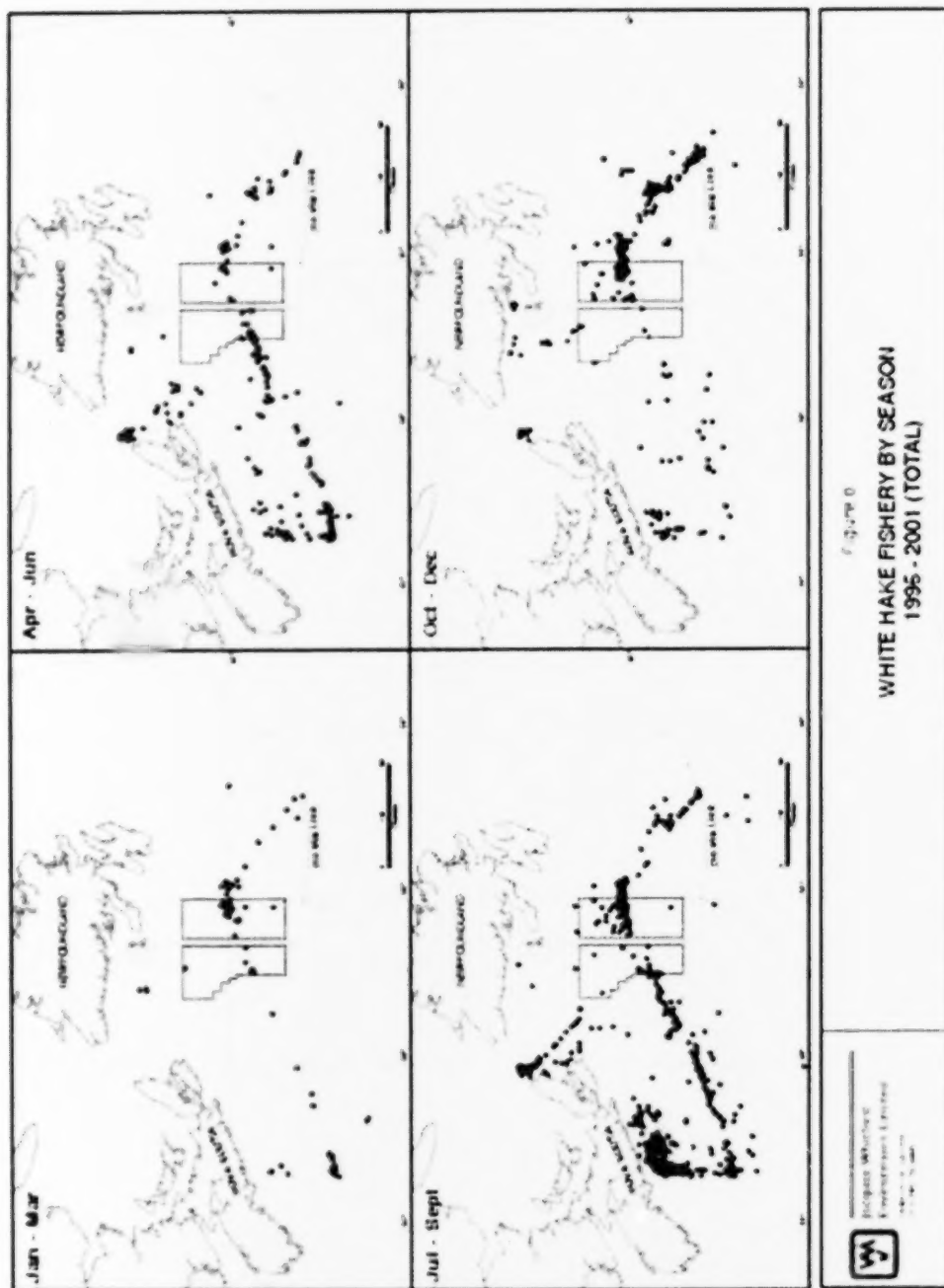


Figure 0
 WHITE HAKE FISHERY BY SEASON
 1996 - 2001 (TOTAL)


 Department of Fisheries and Aquaculture
 Newfoundland and Labrador
 St. John's, NL A1B 4X6

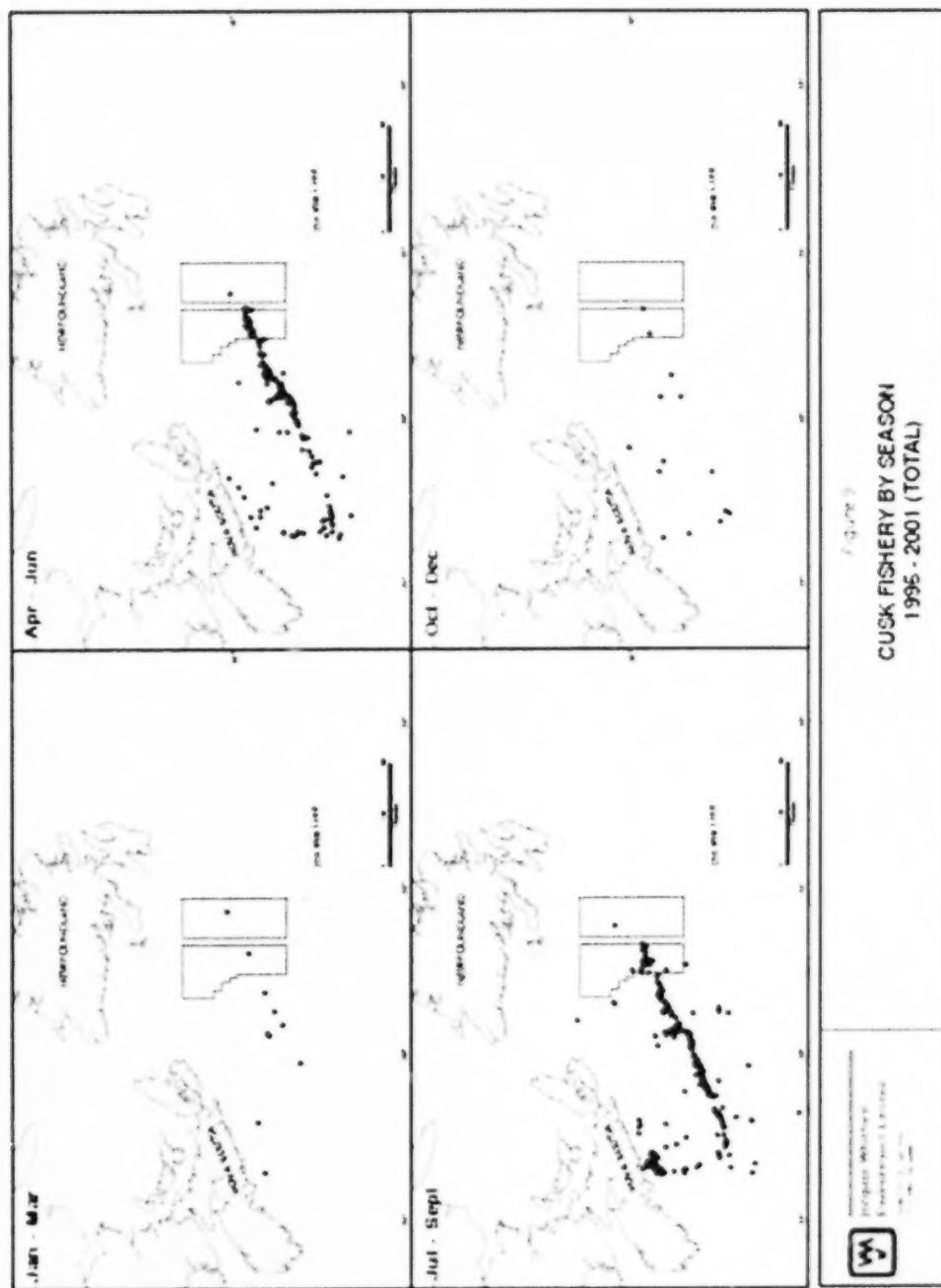
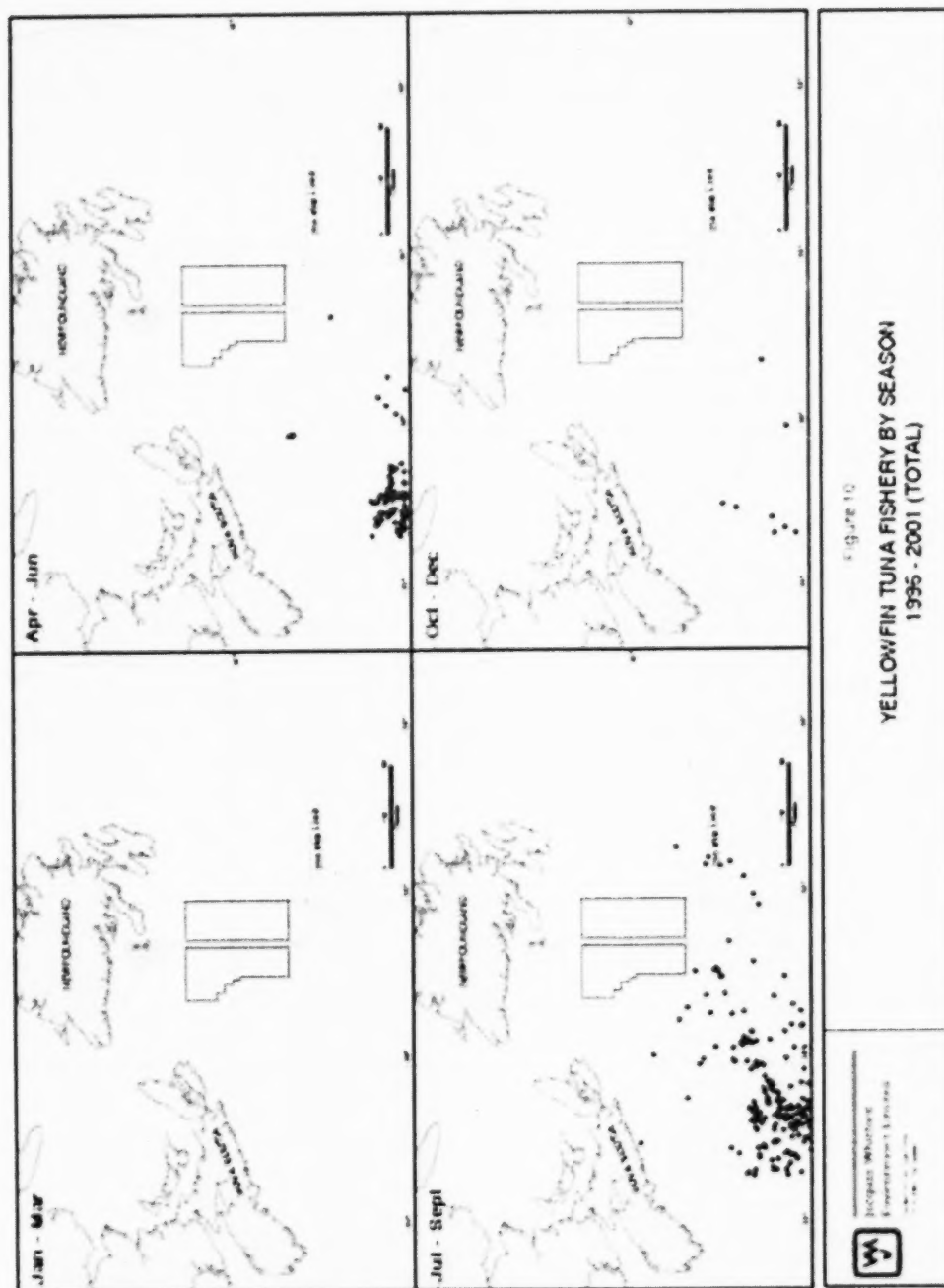
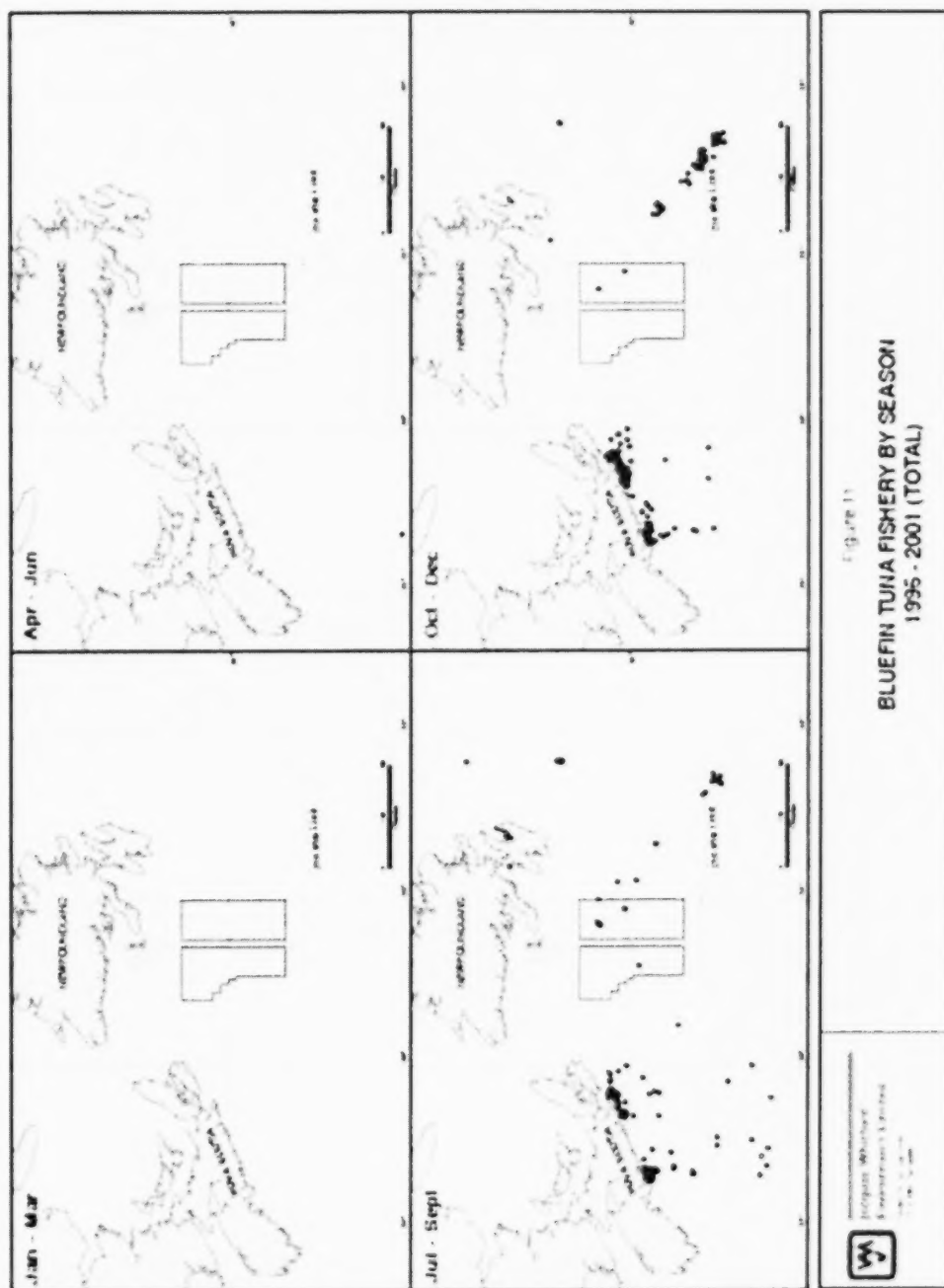


Figure 3
**CUSK FISHERY BY SEASON
 1995 - 2001 (TOTAL)**

Prepared by:
 Fisheries Research Board of Canada
 1000 University Avenue
 St. John's, NL A1B 4X6







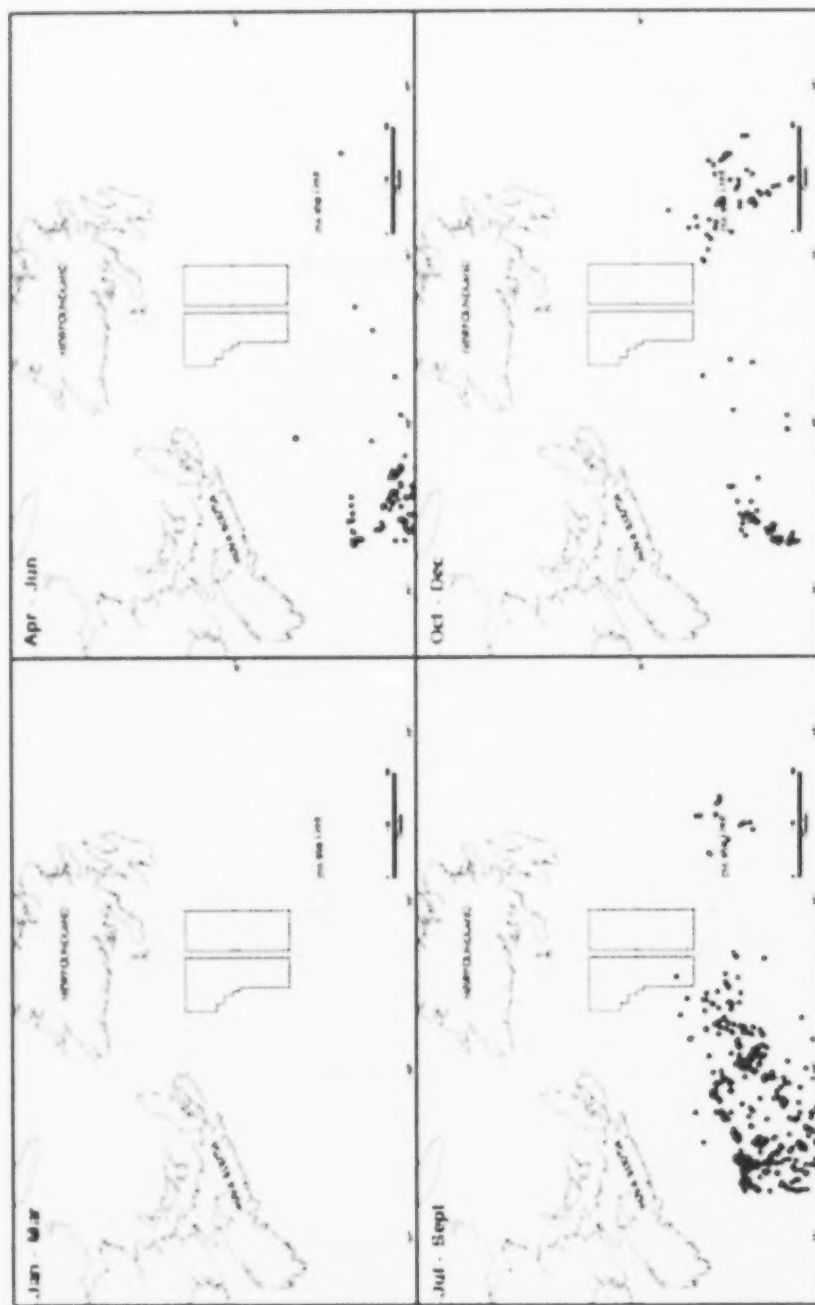
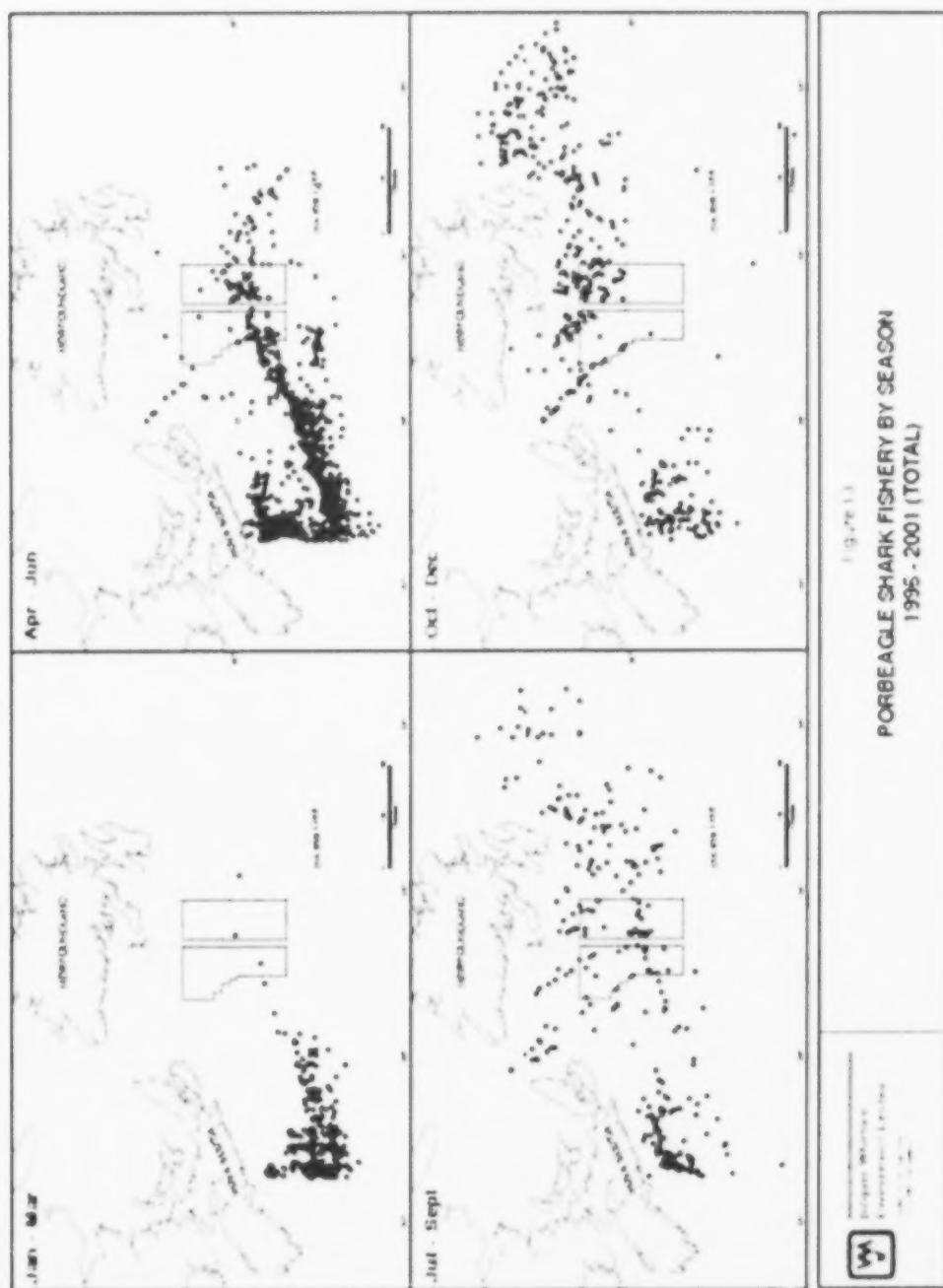


Figure 12

BIGEYE TUNA FISHERY BY SEASON
1995 - 2001 (TOTAL)



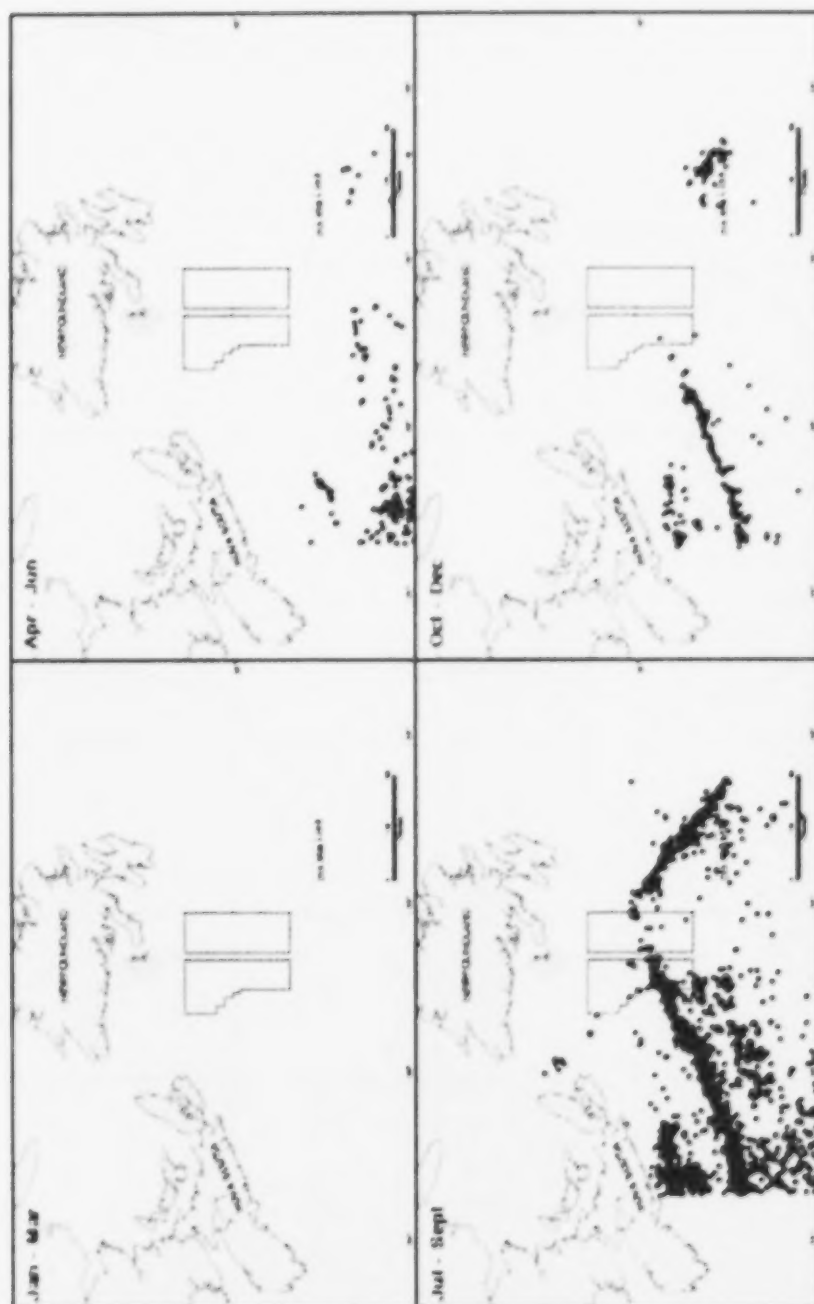


Figure 14
SWORDFISH FISHERY BY SEASON
1995 - 2001 (TOTAL)

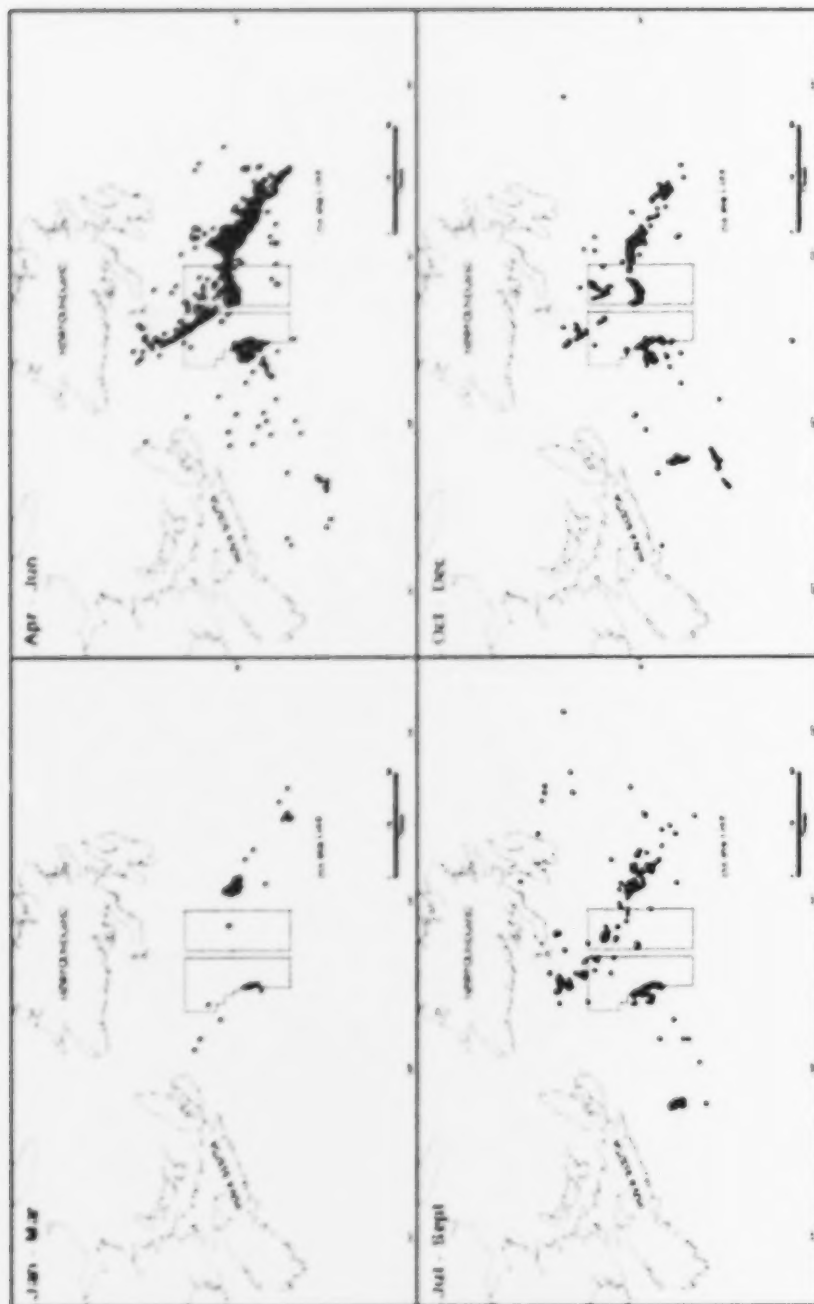


Figure 10
SKATE FISHERY BY SEASON
1995 - 2001 (TOTAL)



International Council for the
Exploration of the Sea
ICES

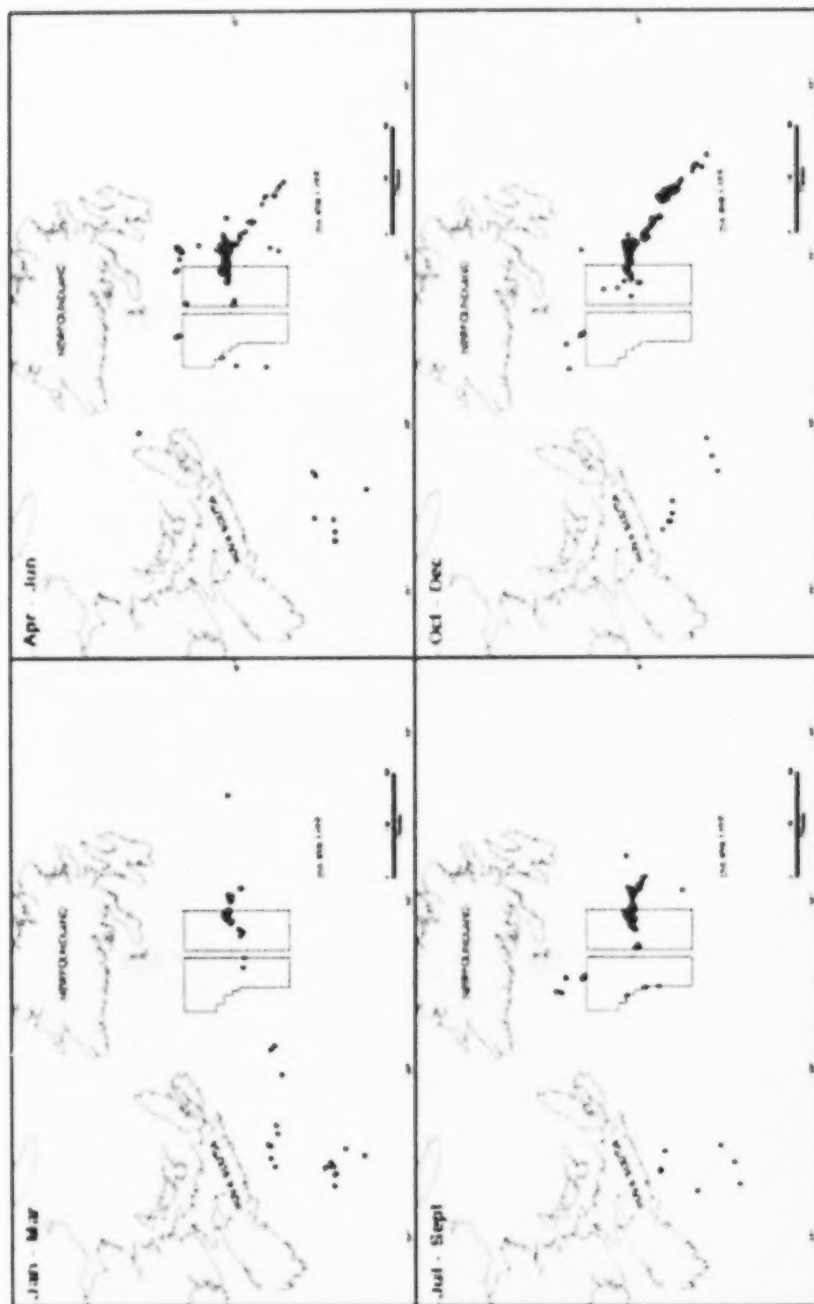
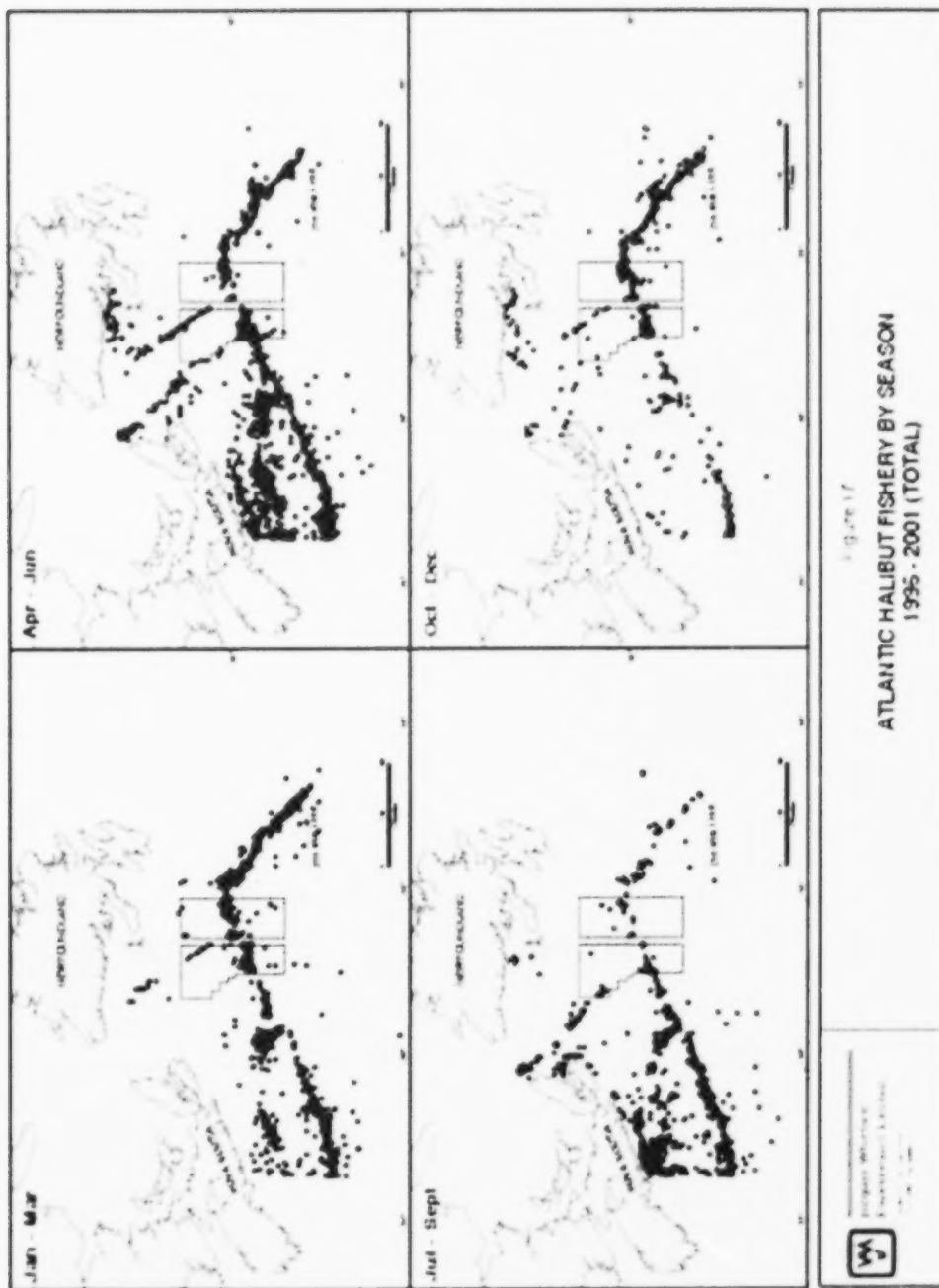
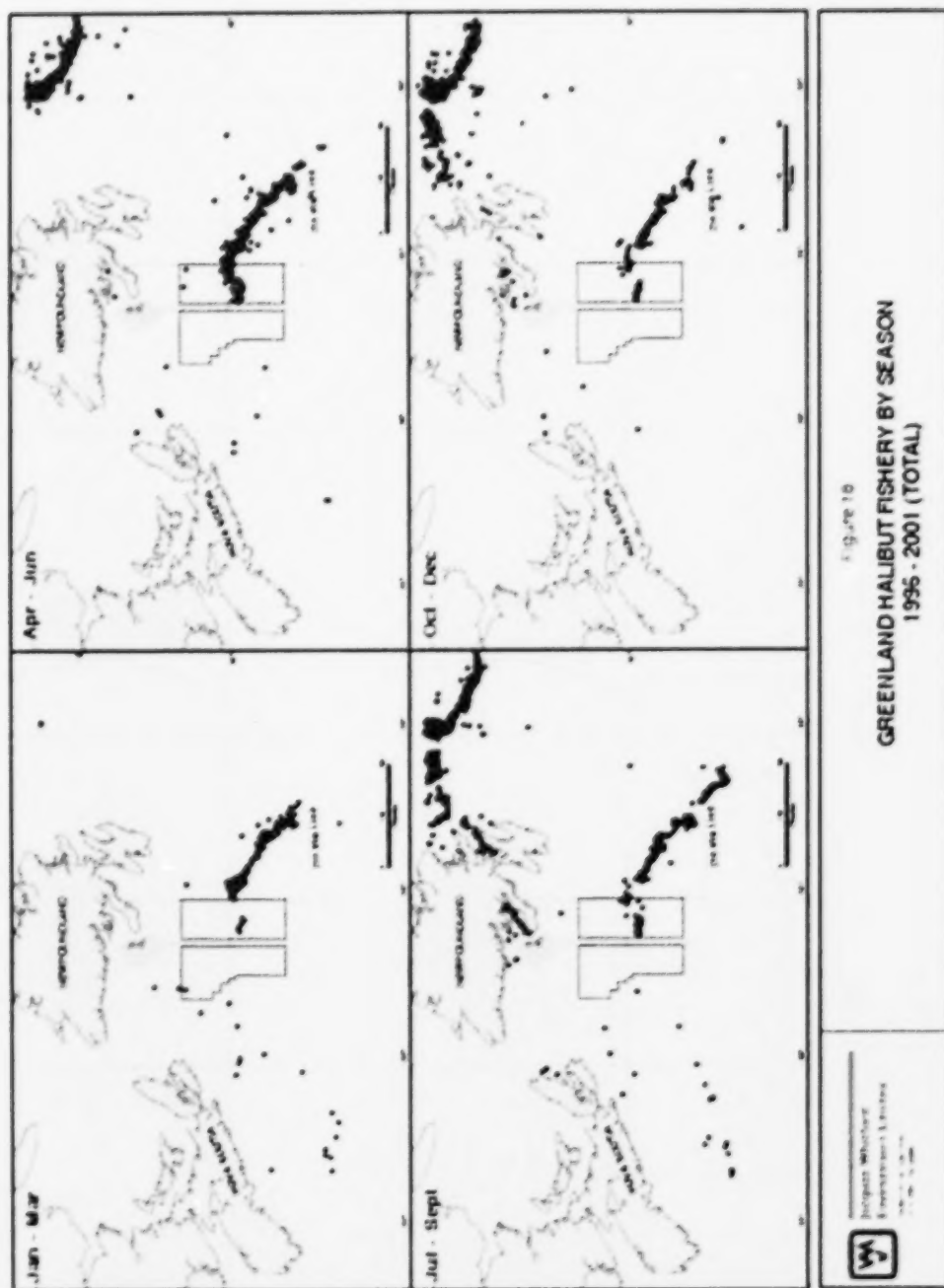


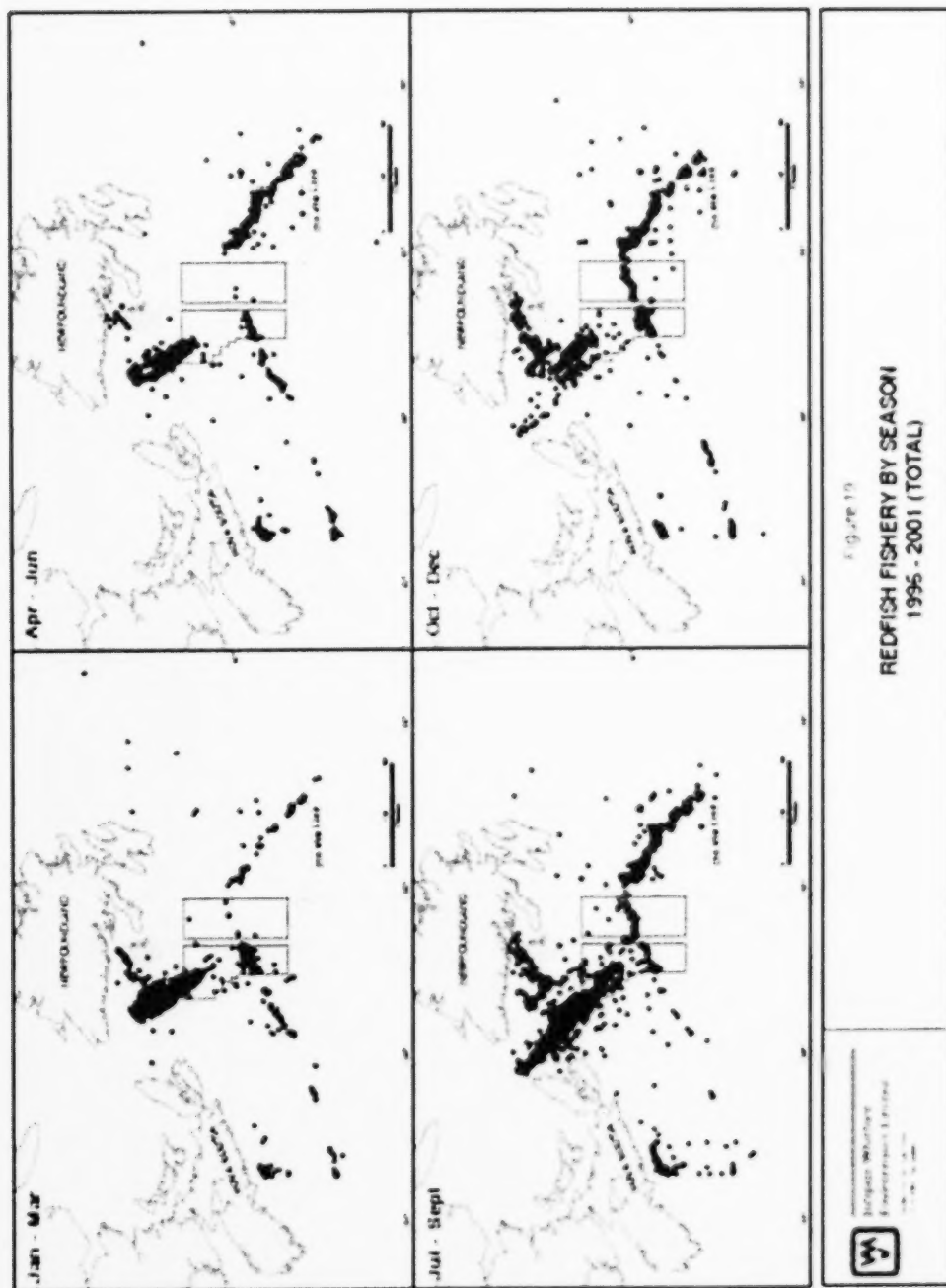
FIGURE 16
MONKFISH FISHERY BY SEASON
1995 - 2001 (TOTAL)

Prepared by:
Fisheries Research
Department of Fisheries
and Aquaculture
Science









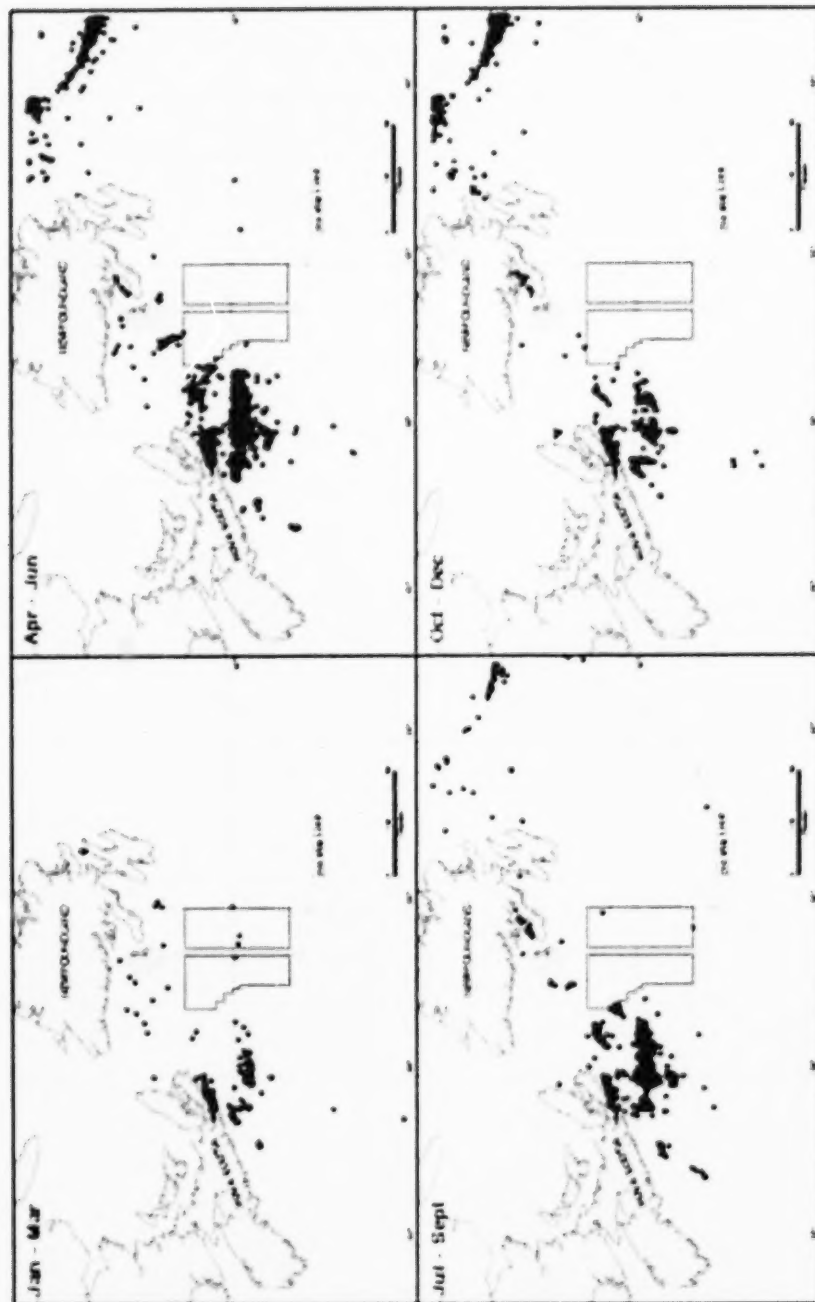
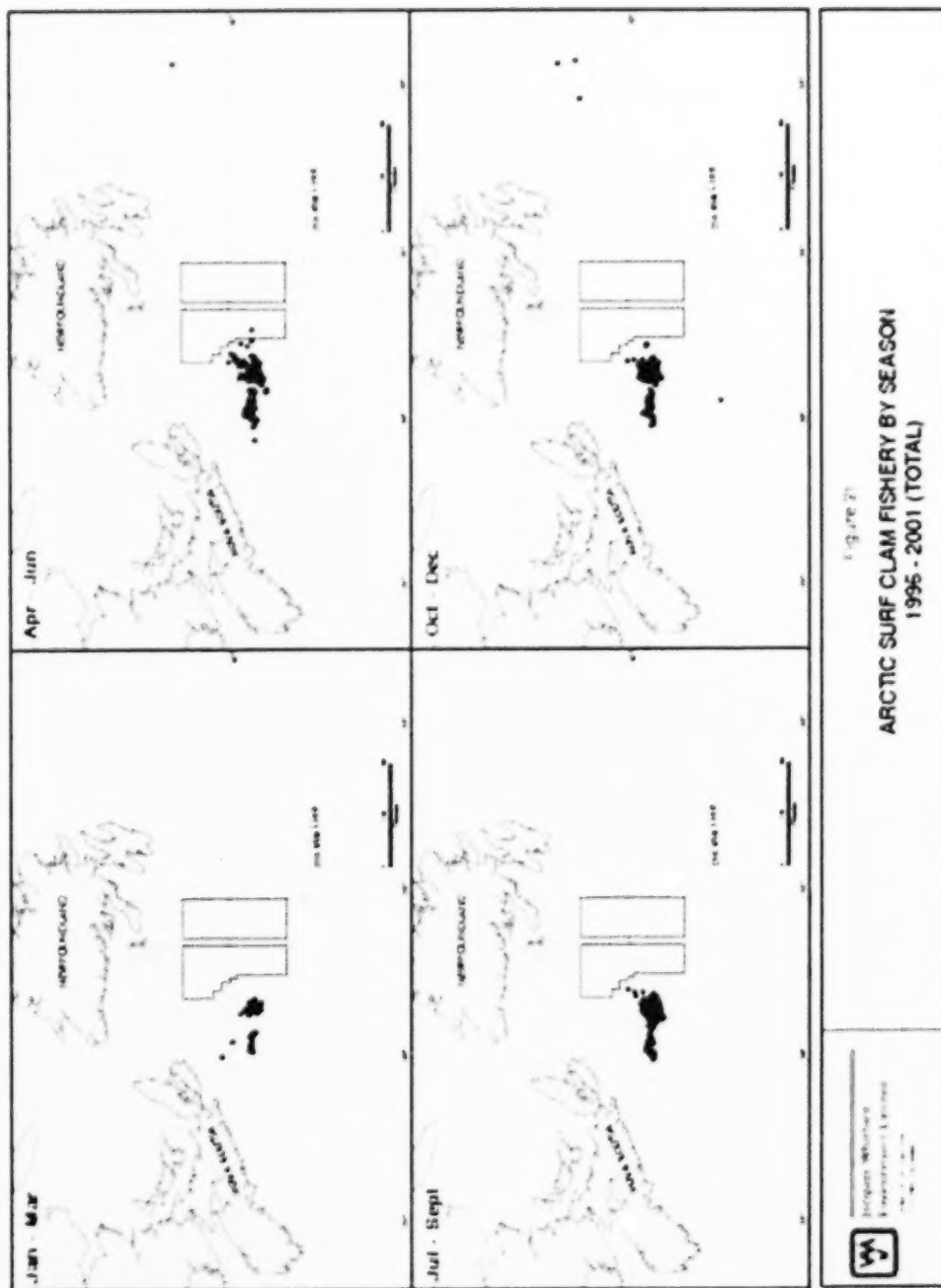


Figure 20

SHRIMP FISHERY BY SEASON 1996 - 2001 (TOTAL)



 National Oceanic and Atmospheric Administration
 Department of Commerce
 Washington, D.C. 20513



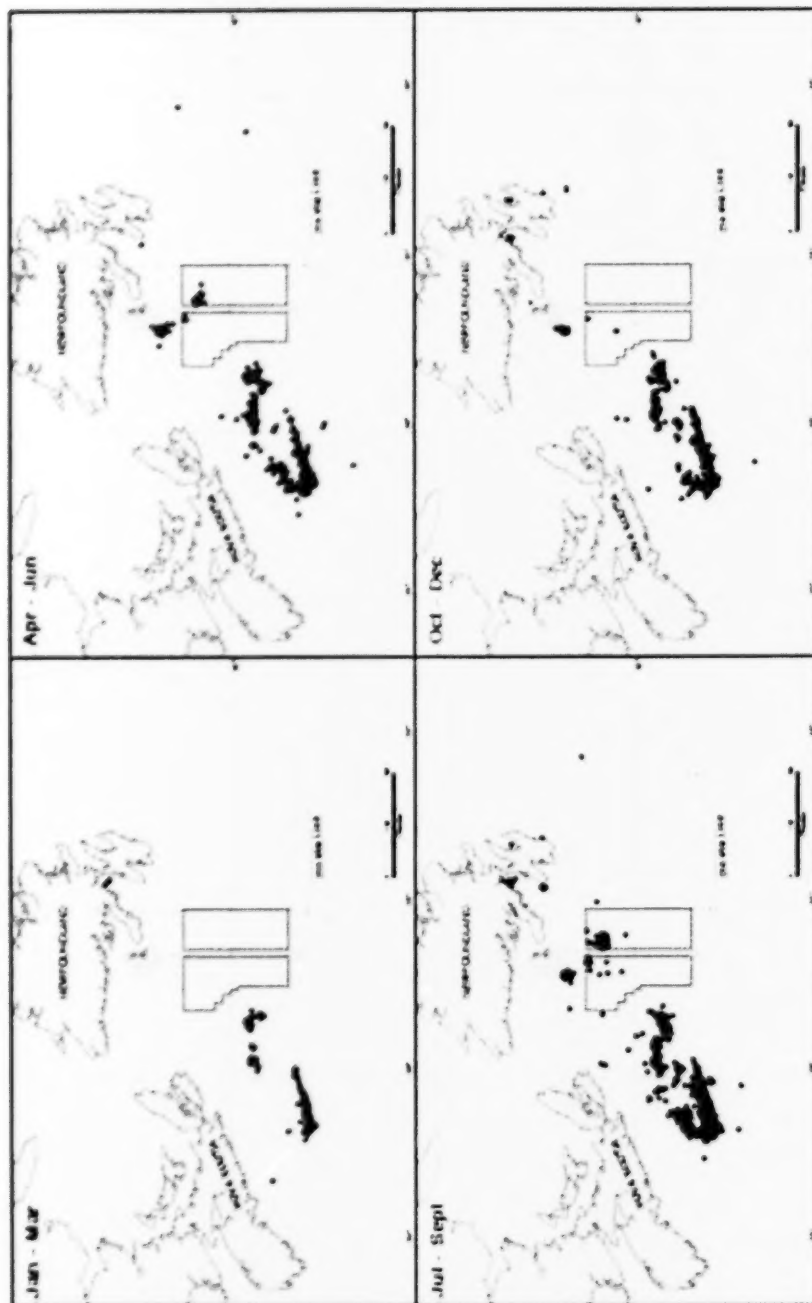
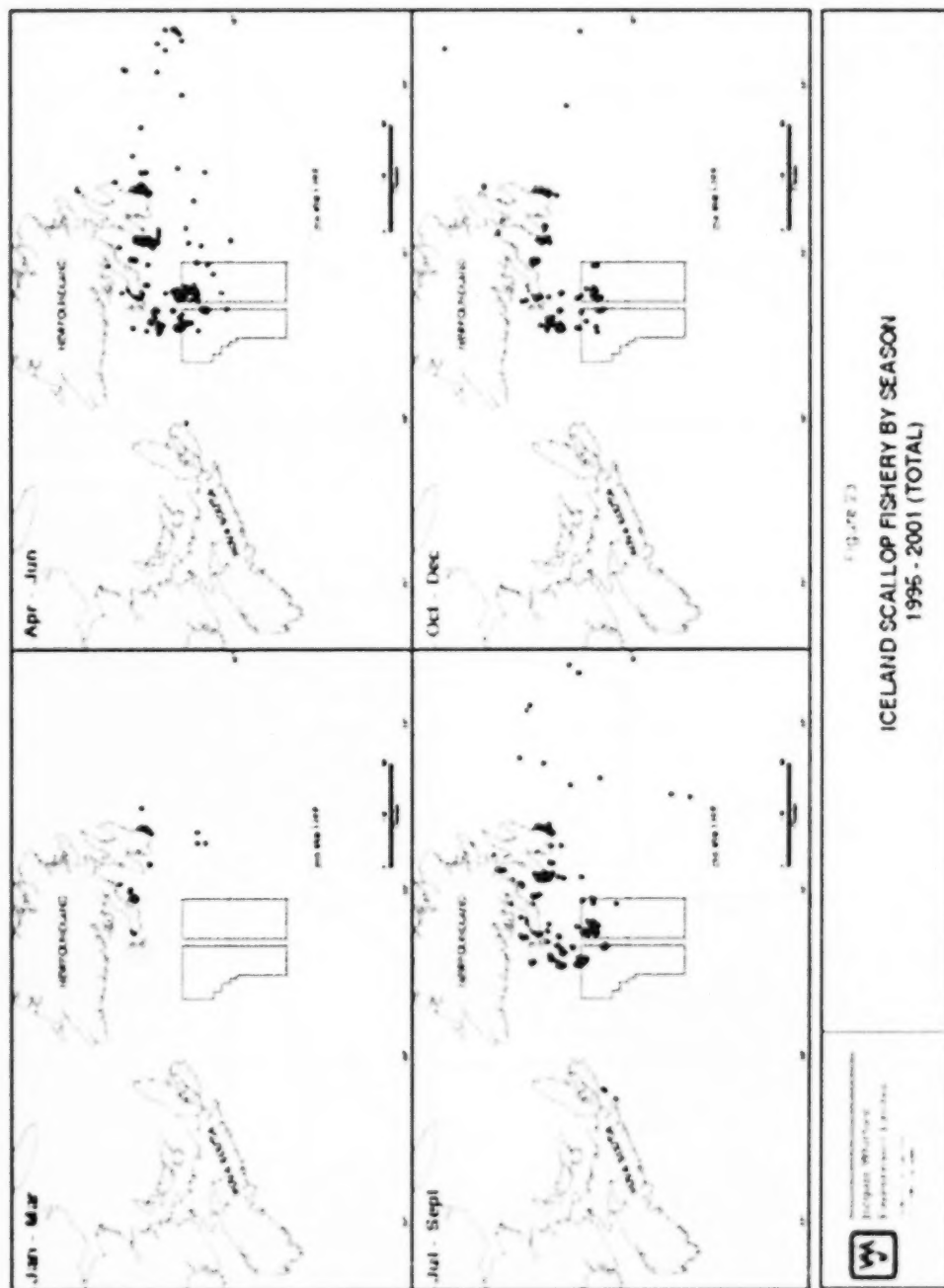


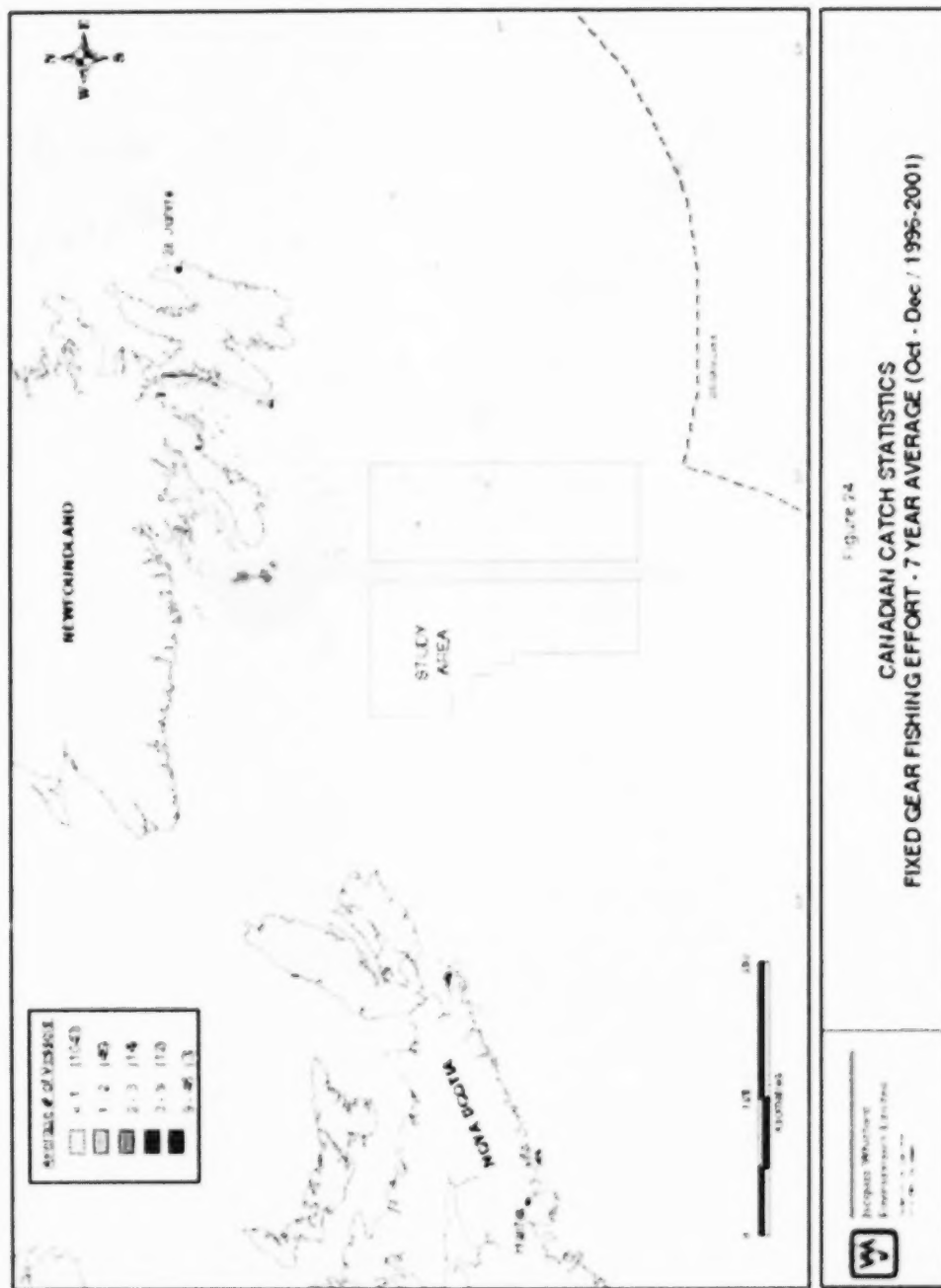
Figure 22

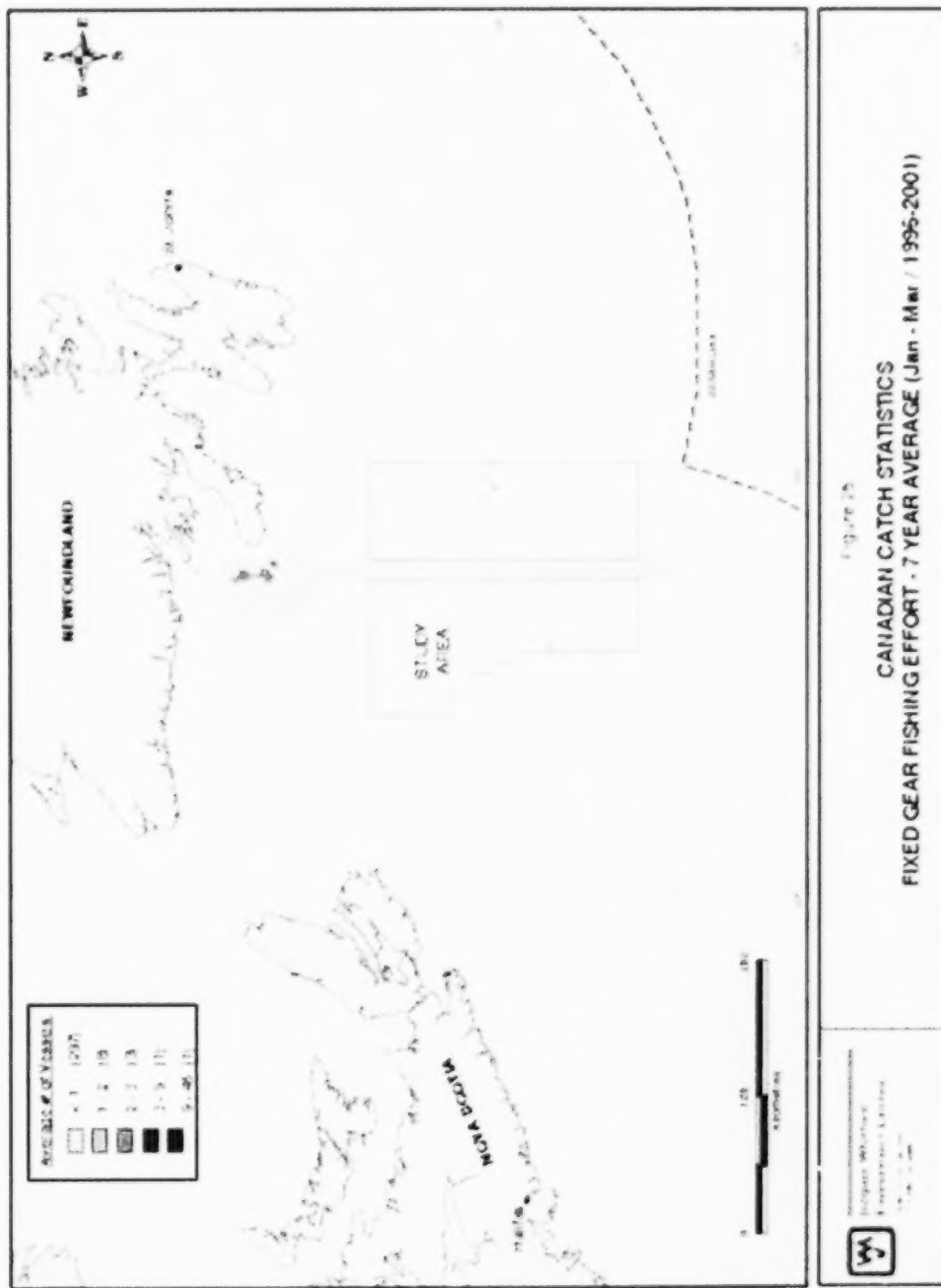
SEA SCALLOP FISHERY BY SEASON 1995 - 2001 (TOTAL)

Project: Wharfedale
Environment Unit









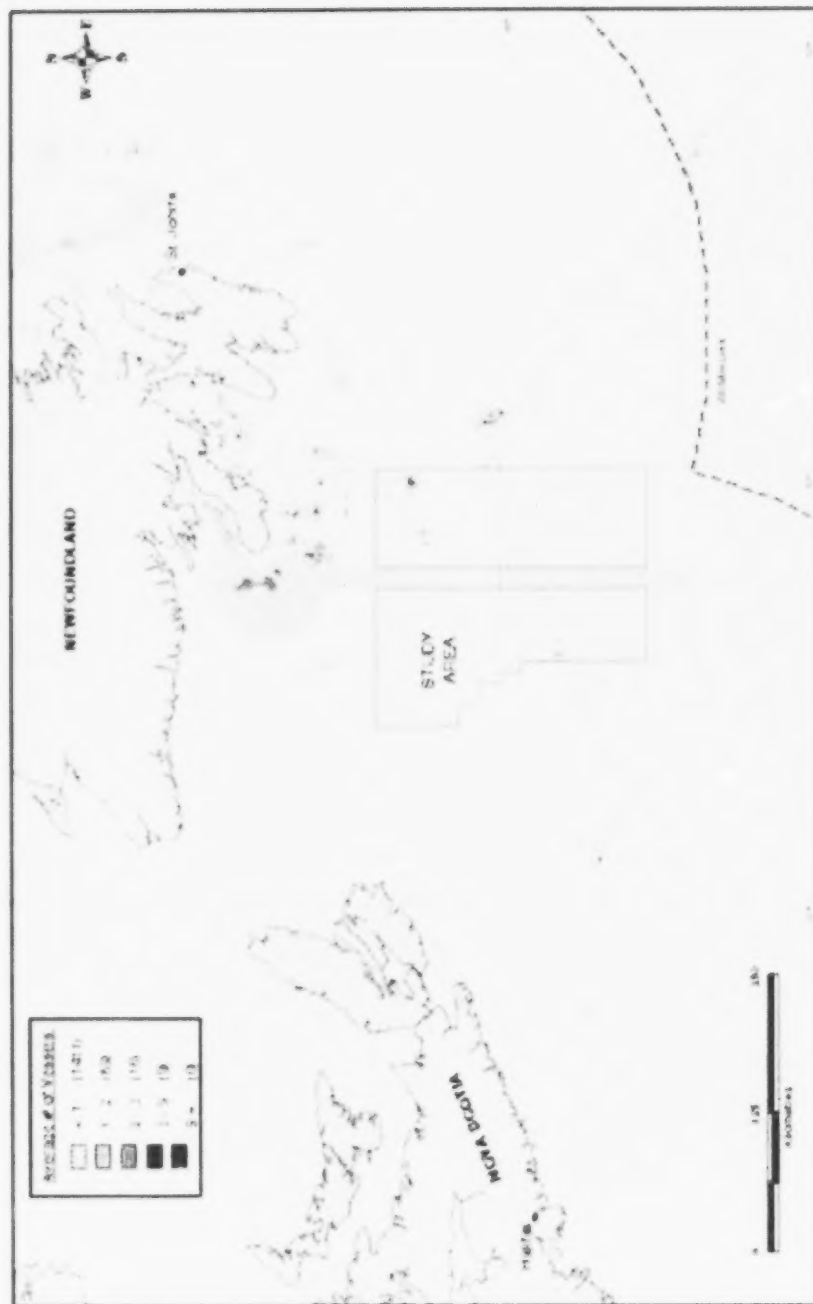


Fig. 2

CANADIAN CATCH STATISTICS
FIXED GEAR FISHING EFFORT - 7 YEAR AVERAGE (Apr - Jun / 1995-2001)



Department of Fisheries and Aquaculture
Canada

Project: Newfoundland
St. John's Region

Map of St. John's Region

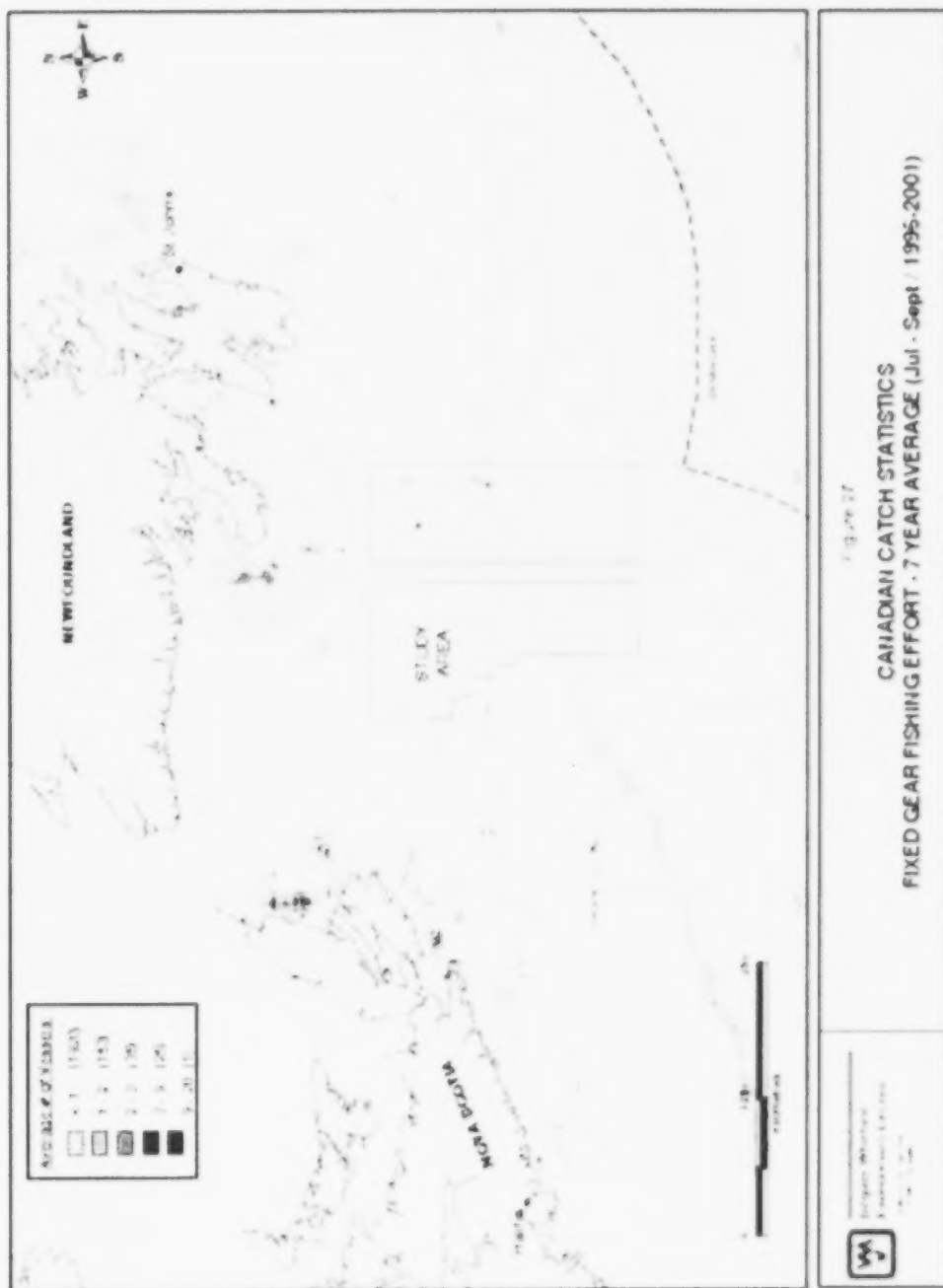


Figure 27
CANADIAN CATCH STATISTICS
FIXED GEAR FISHING EFFORT - 7 YEAR AVERAGE (Jul - Sept / 1995-2001)

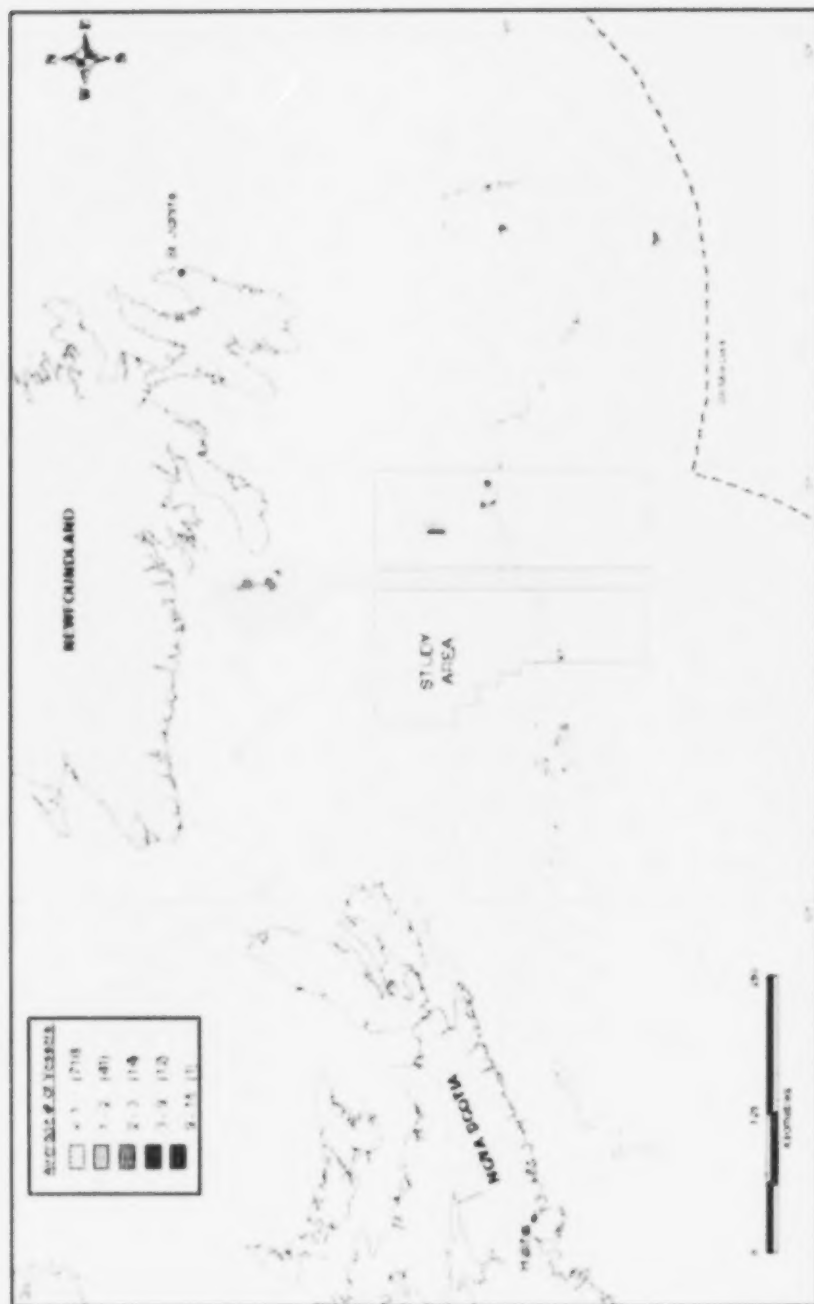


Figure 26

CANADIAN CATCH STATISTICS
MOBILE GEAR FISHING EFFORT - 7 YEAR AVERAGE (Oct. - Dec. / 1995-2001)



Department of Fisheries and Aquaculture
Atlantic Region

